Tangible Interactions with Acoustic Levitation

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ABSTRACT

Acoustic Levitation can hold millimetric objects in mid-air without any physical contact. This capability has been exploited to create displays since being able to position mid-air physical voxels enables for rich data representations. However, most of the times interesting features of acoustic levitation are not exploited. Acoustic Levitation is harmless and sound diffracts around objects, thus we can insert our hand inside the levitator and touch the levitated particles without harmful effect on us. In this demo, we showcase more tangible interactions with acoustically levitated particles by passing acoustically-transparent structures through the particles, manipulating particles in mid-air with wearable levitators or by moving multiple particles with direct manipulation. We hope that this demo provides a more tangible experience of acoustic levitation. Since all the presented devices are Do-It-Yourself, we encourage visitors to experiment further with acoustic levitation.

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KEYWORDS

Acoustic Levitation; Tangible Interaction; Floating Voxels; Ultrasonic Haptic Feedback; Holographic Acoustic Tweezers; Data Physicalization

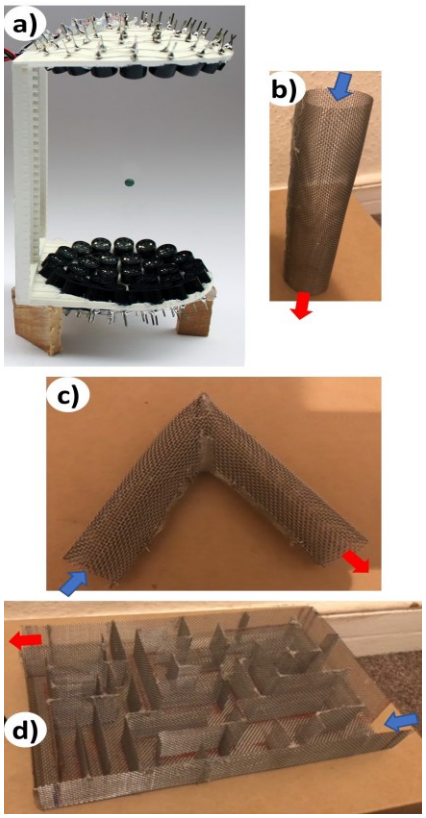

Figure 1: a) Levitator with a 3 mm diameter particle in the centre. The structures that need to be pass through the particle: straight tube (b), bent tube (c) and a maze (d).

1 INTRODUCTION

Acoustic levitation uses the radiation forces generated on objects that are inside an acoustic field [2], some acoustic fields produce converging forces at a point that can trap a particle in mid-air [1]. Using sound to hold objects in mid-air has multiple advantages compared to optical or magnetic levitation [8]. For instance, different materials can be trapped, the reach is normally larger, the range of particle trapping can be adjusted by the operating frequency, and it is safer. For these reasons, acoustic levitation is used for containerless transportation [4], handling biological samples [19], and levitation of living things [23] or even food [21].

The single-axis levitator is the most common setup. In it, a standing wave is created between an ultrasonic emitter and an opposed reflector (or another emitter), the particles are trapped at the nodes of the standing wave [22].

Using acoustic levitated particles to display information is an emerging field of research [16]. For example, levitated particles have been used to represent 3D trajectories [18], screens [20], dynamic charts [17], or to augment existing displays [12]. Novel interaction techniques are appearing to interact with these levitating representations of information [6][5]. Multiple advances in phased-array technologies and algorithms have made significant progress on the capabilities of acoustic levitation: particles are no longer static and can be dynamically moved in 3D [16][18][10], particles larger than the wavelength can be trapped [11][7], and individual control on multiple particles is possible [9].

In these demos we would like to highlight some characteristics of acoustic levitation that are often not fully exploited. On the one hand, we will focus on conveying that acoustic levitation is harmless to our skin, so the users can introduce their hand in the acoustic levitators to touch the particles or pass other structures around them. On the other hand, sound diffracts around objects [15], thus the hand of the user or other objects will not disturb the levitation if they are inserted in specific orientations, even if they are placed close to the particles or touch them.

2 DEMOS

2.1 Demo 1: Pass Acoustically-transparent mazes and tubes through a levitated particle

In the first demo, acoustically-transparent structures are passed through a levitated particle. If the structures touch the particle, the later will fall and the user will need to start again. This is like the game in the fairs in which a metallic hoop must be passed along a gnarly wire, if the hoop touches the wire, the player loses. The acoustic levitator is a standing-wave levitator similar to BigLev [8] and the particles are Styrofoam particles of 3mm diameter. The structures are made of fabric and metallic mesh (1 mm spacing). Structures of increasing difficulty are available: a straight tube, a bent tube and a maze (Figure 1). We tried to autodetect the touch event by charging the particle with high-voltage and then connect the metallic structure to a detection circuit, but the detected spike was significantly lower than the background noise.

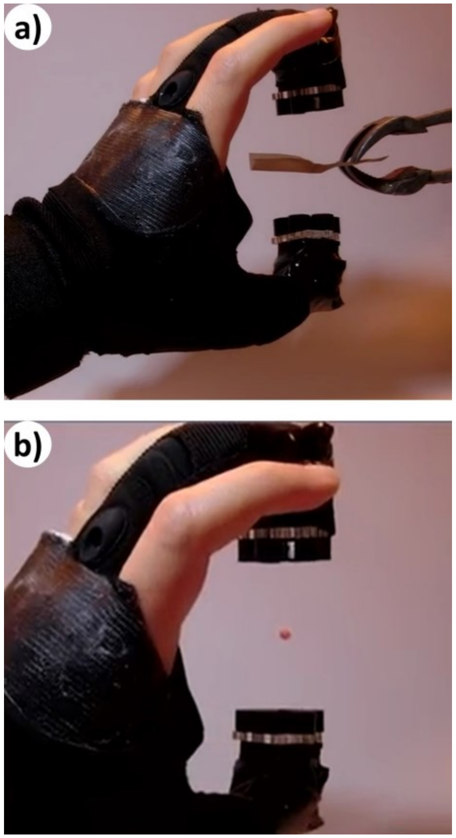

Figure 2: Two wearable levitators attached to the heart and thumb finger, a standing wave is created between them. a) the user is picking up a particle that is resting in the acoustically-transparent mesh. b) the particle remains between the fingers.

2.2 Demo 2: Thimblets, Mid-air Manipulation of Particles with Wearable Levitators

In the second demo, small wearable levitators are attached on the thumb and heart finger of the user, a standing wave is generated between them and particles are trapped inside (Figure 2). Particles are initially resting on the table and over an acoustically-transparent platform. The user can pick the particles by placing the thumb opposed to the heart, then particles will be trapped between them. Apart from picking particles and releasing them, other maneuvers are possible without the aid of a computer controlling the emission. The distance between the fingers determines the strength of the standing wave and standing waves can intersect between them. This makes possible to translate one particle from one hand to another or to combine particles from each hand into a single hand. These capabilities and hardware were described in Gauntlev [14] but this is the first time that it will be demonstrated to the public and available so that everyone can try the maneuvers.

2.3 Demo 3: Direct Manipulation of Multiple Particles with Integrated Haptic Feedback

In the third demo, a set of particles is held in mid-air and the user can move them independently. The user can insert the hand in the levitator and pinch near a particle to select it. A selected particle will follow the user's finger as he or she moves the hand around. Releasing the pinch deselects the particle. Different compositions can be created in this way and are shown in Figure 3.

Haptic feedback is generated around the particles when the user is selecting a particle, this facilitates the interaction. This feedback is generated by applying amplitude modulation on the wave emitted by the transducers. The modulation is a sinusoidal wave of 200 Hz, this frequency is the most common for ultrasonic-induced haptic feedback [3].

The system is composed of two opposed arrays separated by 23 cm, this system is similar to the one previously presented by Marzo and Drinkwater [9]. The system uses a Leap Motion to detect the fingers positions, a custom software developed in Java and the platform Ultraino [13] to control the phased-arrays so that they create the traps at the target positions.

The presented manipulations are simple, i.e. only one particle can be translated at the time. However, we think that this demo would be sufficient to engage the audience in a conversation about more advanced techniques for multiple particles and using multiple hands. For instance, when two particles are selected with two hands, rotation or scaling of the "levitated cube" could be performed.

3 CONCLUSION

We have presented 3 demos focused at providing a more tangible experience with acoustic levitation. The user will experience an interaction that leverages on the fact that unless other forms of levitation, acoustic levitation is harmless to our skin and sound can diffract around objects. After experiencing the demos, the participants can create their own levitators to experiment further since they are available at www.directfromthelab.com

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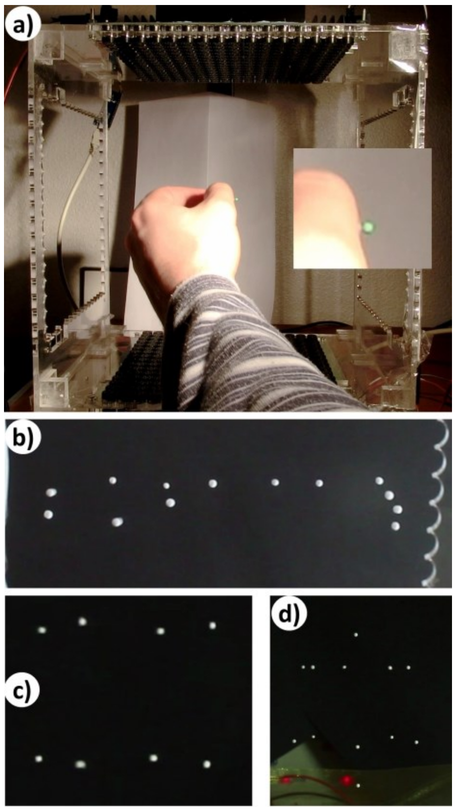

Figure 3: a) A controllable standing wave levitator, the user can insert the hand and make a pinch gesture near the particle, as the user moves the hand the particle follows. b,c,d) Compositions that can be created by translating the particles to different locations.

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