Levi-loop: A Mid-Air Gesture Controlled Levitating Particle Game

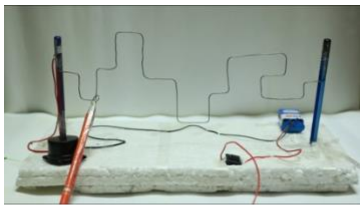

Figure 1: Traditional, do-it-yourself, wire-loop game setup composed of a wire, a loop, a battery and a buzzer.

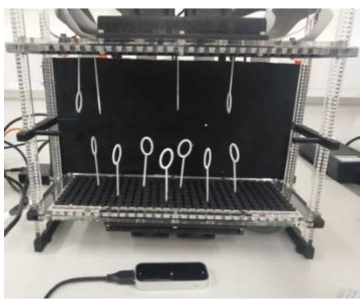

Figure 2: Levi-loop game setup composed of a phased ultrasound array (two sided), a collection of 3D printed hoops, a levitating particle, and a Leap Motion controller.

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Abstract
Acoustic levitation offers a novel alternative to traditional volumetric displays. With state-of-the-art hand-tracking technology, direct interaction and manipulation of levitating objects in 3D is now possible. Further, adding game-elements like completing simple tasks can encourage participant exploration of new technologies. We have therefore developed a gesture controlled levitating particle game, akin to the classic wire-loop game, that combines all these elements (levitation, hand-tracking, and gameplay) together with physical obstacles. Further, we have designed a gesture input set that constrains false triggering gestures and dropping of the levitating particle.

Author Keywords
Acoustic levitation; game; ultrasound; gesture input.

CSS Concepts
• **Human-centered computing~Human computer interaction (HCI)**; *Gestural Input*

Introduction
A wire-loop game, also known as “Buzz wire”, is a classic childhood game that involves guiding a metal loop along a serpentine length of wire, without touching the loop to the wire (see Figure 1). The loop and wire are connected to a power source such that, if they touch, they form a closed electric circuit. A light or a

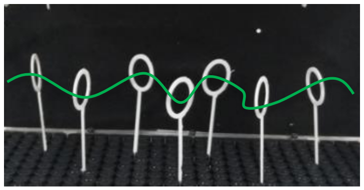

Figure 3: Zoom in to the obstacle track highlighting the intended trajectory in green. More complex tracks can be created by adding loops or making their diameter smaller. A competitive time requirement can also be imposed.

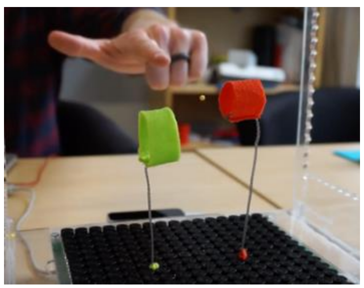

Figure 4: Point-and-move the levitating particle through a series of cylinder-shaped fabric or 3D printed loops. Gesture tracking is achieved here by a Leap Motion controller however other tracking hardware could be substituted in as required. A minimum requirement is to track fingertip 3D location with an accuracy smaller than the loop diameter.

buzzer is also connected to the circuit so that when the loop and wire touch, a light or buzzing noise signals the failure state of the game. The difficulty of the game depends in part on the shape of the twisted wire and the size of the loop; e.g., a smaller diameter loop will require more skill to successfully navigate without touching the wire.

Virtual versions of this game also exist, in which the pointer takes the place of the wire loop and must be guided along a narrow, twisting path without touching the sides. Both physical and virtual versions require patience and well-developed hand-eye coordination. In fact, traditional and VR versions of the wire-loop game have been proposed for assessment and rehabilitation of upper-body motor skills for people with dexterity impairment after stroke [2] [3].

We present an interactive levitating wire-loop game called "Levi-loop", where the player must guide a small levitating object along a twisting track of obstacles. We use a phased array of ultrasonic speakers to create levitation traps [7] that hold a small polystyrene particle in the air (see Figure 2). We also use a Leap Motion controller to track the user's index finger position. We then couple the user's index finger movements to the location of the trap, thus enabling the user to move the levitating particle in 3D space in real-time. Looped obstacles are created using 3D printed structures and acoustically transparent fabrics (shown in Figure 3 and 4) and positioned as to emulate the twisting path of the wire. The game objective is for the player to guide the particle through the loops from start to finish, without the particle touching them and falling out from its trap.

Demo Contribution

We explore the challenges of precisely manipulating a mid-air levitating particle using in-air hand movements. Recent work has shown that users can successfully interact with levitating objects when not constrained by obstacles [1], [4], but it is not clear how other objects affect the degree of control afforded by state of the art optical hand tracking equipment, such as the Leap Motion controller, nor how they manifest in human performance, e.g., relating to the accuracy-speed tradeoff described by Fitts's law. Levitation also has unique challenges not present with other mid-air control interfaces, e.g., the dynamics, agency and latency of moving a levitating particle through ever-harder obstacle tracks as seen in Figure 3. Levi-loop is thus an interesting new testbed platform that uses gameplay to explore these novel challenges, whilst introducing CHI attendees to this novel type of user interface through a fun and interactive experience.

We also explore the challenges of creating physical interfaces with levitating particles [5]. Fabricating other objects (e.g., the loops) to be placed within the levitation volume is not straightforward, as the physical objects may disturb the ultrasound waves that need to be precisely controlled to enable successful and reliable levitation. We address these challenges using acoustically transparent materials [8] and 3D-printed objects with a cross-section smaller than the wavelength of the ultrasound as to minimize deflection.

Background

Acoustic levitation creates invisible forces around small particles for holding them in mid-air and it can levitate low density materials like polystyrene, various liquids or food [10]; the opposite of magnetic levitation which

Figure 5: Acoustic levitation system [10] displays an abstract floating butterfly. A levitating particle is illuminated using RGB LEDs to control the color of the scattered light. Persistence of vision causes the glowing dot to appear as a continuous 3D image. Further, parametric audio and mid-air haptics are multiplexed in time and space to create a multimodal volumetric display. Picture credit: Eimontas Jankauskis University of Sussex.

only can levitate magnetic material. There are many ways of achieving acoustic levitation. The usual method is placing particles at the nodes of acoustic standing waves, however, the movement of the particle is then limited to the direction of the waves. Another method is the creation of acoustic traps that hold particles in one place. The traps are essentially small pockets of low sound pressure surrounded by high pressure. Moving the trap locations results in manipulating the levitating particles in 3D space. To create these moving levitating acoustics traps we electronically modifying the amplitudes and phases of an ultrasound phased array. Generally, the bigger the array the better, stronger, and sharper the traps are. The geometry of the array (e.g., one or two sided) is also important. Recent advancements have enabled the non-contact, high-speed manipulation of matter to create multimodal volumetric displays as seen in Figure 5 [6].

Acoustically transparent structures are objects that do not interact with the created acoustic field. In this demo we can create acoustic traps to hold particles that are guided through acoustically transparent structures. The material of these structures can be made with felt [5], special fabrics [8] or a solid mesh [10]. Also, small structures smaller than the ultrasound wavelength are effectively acoustically transparent.

Here, inspired by the traditional wire-loop game, we take a fresh approach that combines acoustics levitation, acoustically transparent structures, and precision gesture control using optical tracking technology to create a fun and interactive game experience.

Demo Description

The Levi-loop game interaction is summarized in Figure 6. The acoustic levitation device used consists of two 9x27 arrays of 40 kHz ultrasound transmitters (each 1 cm in diameter). The arrays are separated by 18 cm and positioned facing each other, with one on the table surface and one directly above it, held by an adjustable Perspex frame (see Figure 2). The internal volume of the device (the 'levitation space') is {28.8 x 9.1 x 16.5} cm. The levitating particles used are expanded polystyrene beads (diameter 1-3 mm). This basic apparatus was developed in [9]. Here, we have improved and expanded on its capabilities through software, the gesture input set, and the obstacle track.

Our Levi-loop 'maze' consists of 3D-printed loops (using PLA) and acoustically transparent fabrics (e.g., acrylic felt and organza). The loops are held in place by the top or bottom ultrasound arrays. The fabric is shaped into a cylinder and held in place by the loops, placed intermittently along it (see Figure 3 and 4). Gameplay difficulty can be adjusted by reconfiguring the maze: e.g., using loops with a narrower diameter, replacing maze segments with opaque materials to obscure the particle, and twisting the maze to add more complicated changes in direction.

A Leap Motion controller running the latest SDK Orion v4.0 is used to track the user's fingers in air, for controlling the levitating particle; the trajectory of the user's index finger is translated into the levitation space as input to the game (like in the LeviCursor [1]). We employ point-and-move gestures with an open thumb The thumb extension is used as a clutch, to help the system identify the player and to reduce false-positive gestures (see Figure 6) [4]. Other hand-gestures such

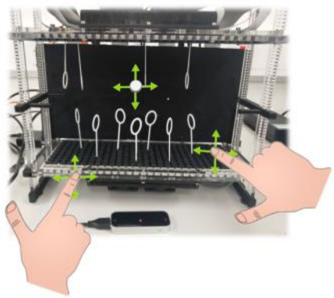

Figure 6: Illustration showing the Levi-loop demo interaction. The player initiates interaction by pointing with her thumb open (as if holding an imaginary gun) to *point-and-select* the levitating particle. The hand is being tracked by the Leap Motion controller. The coordinates of the player's index finger are mapped to levitating particle so that motion is coupled, and the user can *point-and-move* the levitating particle. The player can pause interaction by closing their thumb. The player can re-initiate or continue the interaction from a different location by opening her thumb, as long as her hand is within the field of view of the Leap Motion controller.

as pinch-to-move are also possible and quite stable. Finally, players can reposition themselves and their controlling hand-gesture in mid-play by closing their thumb in order get a better viewing-angle perspective of the maze challenge.

Conclusion

We have described Levi-loop, a novel interactive experience that uses gameplay to reflect on the challenges of precisely controlling mid-air levitating objects in the presence of physical constraints and obstacles. Levi-loop is also an engaging 'hands-on' experience that introduces CHI attendees to acoustic levitation interfaces, an emerging display type seen in the HCI literature and popular press.

Using the Levi-loop platform, we plan to investigate the accuracy-speed tradeoff described by Fitts's law, multiplayer extensions, and how recent projection mapping techniques coupled with rapid levitation movements [6] can be used together with acoustically transparent obstacles to, for instance, replicate the plethora of maze-like arcade games from the 70s and 80s like Pac-Man.

Acknowledgements

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