# Manipulating Scent Particles with Ultrasonic Transducer Arrays

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This research focuses on increasing the perception of immersion within virtual, augmented and multisensory environments. Through a method of ultrasonic particle manipulation – using acoustic standing waves to isolate and control the behaviour of vaporised scent particles – we hope to demonstrate a discreet, sophisticated system which can be used in combination with existing virtual and augmented reality hardware, and which is controlled through in-game actions. Existing systems which rely on fans and fill the space with a scent can be used by multiple people within the same space – this requires less hardware, however; where users are exploring a large virtual space and where actions can trigger scents independently of one another, the overall resolution may suffer. An individual system may therefore provide users with a more accurate, high resolution olfactory image. We believe that immersive gaming, as well as other multisensory environments (museums, exhibitions spaces, marketing) would be enhanced through the introduction of additional sensory stimuli. Our initial experimentation suggests that ultrasonic transducers are a viable method for isolating nebulized essential oils. Our test system, comprised of a TinyLev acoustic levitator [1], and particulate matter sensor was able to detect consistently higher density of vapourised particles within the acoustic field, than readings taken with no acoustic device. The next stage of this research will consist of the development of a bespoke ultrasonic device designed to isolate and direct nebulised scent particles towards the user's airways.

**Keywords:** Smell Resolution, Scent User Interfaces, Ultrasonic Transducer Arrays

## 1 INTRODUCTION

Technologies developed with the aim of providing users with increasingly immersive multisensory experiences continue to focus primarily on audio and visual stimuli. Within the field of HCI, research into the remaining senses; smell, taste and touch is wide ranging, and through the development of increasingly complex and sophisticated systems, may in future be as widely available as a source of sensory stimuli within virtual and augmented multisensory environments. Whilst solutions designed to introduce scent stimuli to VR gaming exist in the form of fan-based systems, these may not be an ideal solution for individual users seeking a more discreet design. The research presented here focuses on developing a discreet and sophisticated solution to introduce scent stimuli to an individual's virtual or augmented environment through use of ultrasonic standing waves.

## 2 RELATED WORK

There is a significant body of research within the area of experimental psychology which explores how we perceive different smells, their link to memory and how, through exposure therapy, smell has been shown to influence behaviour [2, 3]. This research outlines both the breadth and sensitivity of our olfactory perception; the ability to detect and identify approximately 1 trillion different scents [4], but also the limitations. Humans are only capable of perceiving one smell at a time. This can be a compound smell made up of a combination of scents but remains limited to a single scent at any one time. This is important when considering how a system may switch between smells to take advantage of temporal olfactory perception.

Existing research on use of smell stimuli within HCI explores how scent might be used in a broad range of multi-sensory scenarios, from additional in-vehicle warning systems to aid driver awareness and improve safety [5] to augmenting diegetic smells within real world scenarios [6, 7]. The Aroma Shooter is a static, desktop device which projects scented air towards the user for enhanced sensory immersion and can be controlled via various types of app [8]. This system is likely to suffer from a lack of spatial resolution when compared with a fan-based system designed to fill a larger area [9], particularly if the user repositions. A number of these studies utilise existing low-cost technologies designed to deliver smell in domestic and commercial applications such as diffusers and fans. Diffusers use atomisers and fans to permeate a space with scent. However, these approaches create smells which linger over long time periods and large areas. The 'smell resolution' of these systems may be significantly above user perception thresholds, limiting the extent to which virtual and augmented environments can include the emotional and cultural cues which smell can provide. Ultrasonic arrays have typically been applied to levitation and haptic feedback, and more recently to create playful interfaces for taste. In this project we are interested in whether acoustics might be used to enhance spatial and temporal smell resolution through the manipulation of scent particles.

## 3 RESEARCH AIMS

Through a program of research covering the next 3 years, we will look to conduct several experimental studies in which we test the viability of ultrasonics as a method for distributing scent particles to individual users. In each set of experiments scent particles will be dispersed into an ultrasonic field being generated directly in front of a sensor, or a participant's airways [Fig.1]. The intention is for the particulate matter to remain stationary at the focal point of the wave long enough for the participant to breath in and process the scent stimuli.

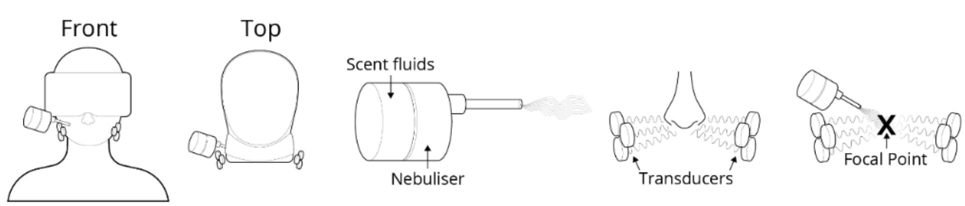


Fig. 1. Particulate matter is dispersed into an acoustic field generated by ultrasonic transducers and directed towards user's airways.

## 4 PRELIMINARY STUDY

The first stage of this research project was to conduct an experiment to test whether ultrasonics would be a viable way of manipulating the behaviour of nebulised particles. This was important in providing the foundation for further experimental design featuring more sophisticated, bespoke ultrasonic hardware. The study was designed to test how much of an increase in particle density was afforded when using a TinyLev ultrasonic levitator, compared to nebulised particles dispersed into the same test area with no device present. The TinyLev uses 76 transducers mounted to two static arrays which are arranged to create a single point of focus at the centre of the field. A particulate matter sensor, capable of detecting the number of particles of specific sizes, was used to record the initial particle count immediately after these were dispersed by the nebuliser, as well as recording time taken for particulate matter to disperse below a certain threshold. The threshold determined by ambient readings taken prior to and between experimental readings.

### 4.1 Method and Experiment Procedure

Initial base readings were taken with the nebuliser and particulate matter sensor placed at 50mm intervals beginning at 300mm and reducing to 100mm. The same process was then repeated with the centre of the TinyLev placed 50mm from the nebuliser. Readings were again taken with the nebuliser and TinyLev remaining static. The distance between nebuliser and particulate matter sensor reduced through moving the sensor toward the nebuliser and through the centre of the acoustic field.

### 4.2 Analysis and Results

Analysis of the data collected suggests that our method of manipulating the behaviour of particles using ultrasonic waves did result in the particulate matter sensor detecting an increased number of nebulised particles. Whilst we are can be reasonably confident that the TinyLev is responsible for this, further experimentation with a bespoke ultrasonic device would allow us to verify the data previously collected and enable us to confirm that the method is viable. Another significant finding was the effect of reflections introduced into the field. Whilst we anticipated that this would present a challenge, through repeated experiments with the particulate matter sensor at different positions within the field we were able to observe changes in behaviour of the particles.

## 5 FUTURE RESEARCH

The next stage of the research process includes the implementation of a custom driver array which will enable much more precise control over ultrasonic transducers, their array shape and size (number). Using the custom driver board, we will be able to run any number of sensors, unlike the TinyLev which utilises a servo motor driver and is somewhat hamstrung by the limited power this produces. The study will also look at the effects of interference on particle behaviour within the ultrasonic field. Reflections, ambient air flow, and breathing each represents a different challenge when attempting to direct microscopic particles towards a user's airways. These challenges are likely to influence the design of our prototype system which we intend to be mounted to existing virtual and augmented reality hardware as shown in figure 2.

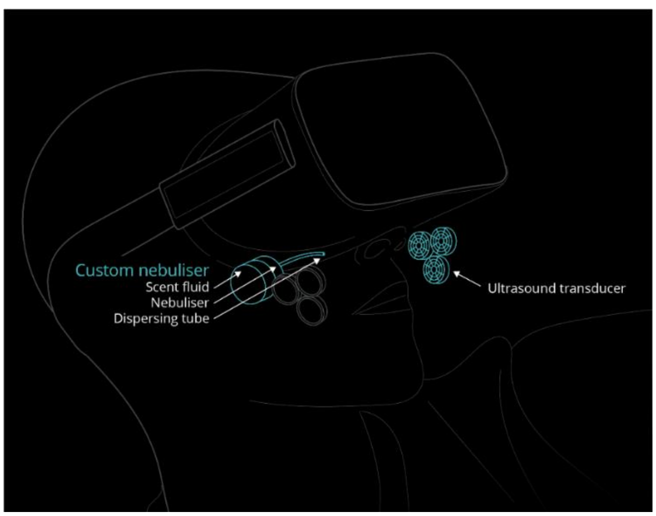


Fig. 2. Impression of how proposed ultrasonic system will work in conjunction with existing virtual reality hardware.

## 6 DISCUSSION

We believe the process of influencing the behaviour of individual scent particles by subjecting them to ultrasonic waves is a potentially viable method of delivering smell stimuli to users in a discreet and sophisticated manner. Evidently there is an interest from users for the introduction of smell stimuli into virtual reality and gaming with fan-based systems already available. We anticipate that our proposed method will provide users a higher level of smell resolution through the ability to dynamically switch between different scents. As humans are limited to perceiving just one scent at a time, how do we best make use of the spatial and temporal resolution afforded by our olfactory perception?

Where the key aim of the research project is to enhance feelings of immersion within virtual and multisensory environments, being able to quickly switch between different scents is perhaps the most important aspect of the work, and differentiates from existing approaches. We also need to determine the types of sensory experience we design for, and how these can represent meaningful immersive interactions. An aspect of smell which may be a benefit but also an obstacle is the persistent characteristic of it when compared to audio and visual stimuli. Whilst an image or sound may be immersive it is less physically intrusive than particulate matter which needs to be consumed by the user in some way. The scents available within a multi-sensory system may be limited and less sophisticated than audio-visual stimuli, however; they might also be the key to more physically immersive and evocative experiences.

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