SoundMist: Novel Interface for Spatial Auditory Experience

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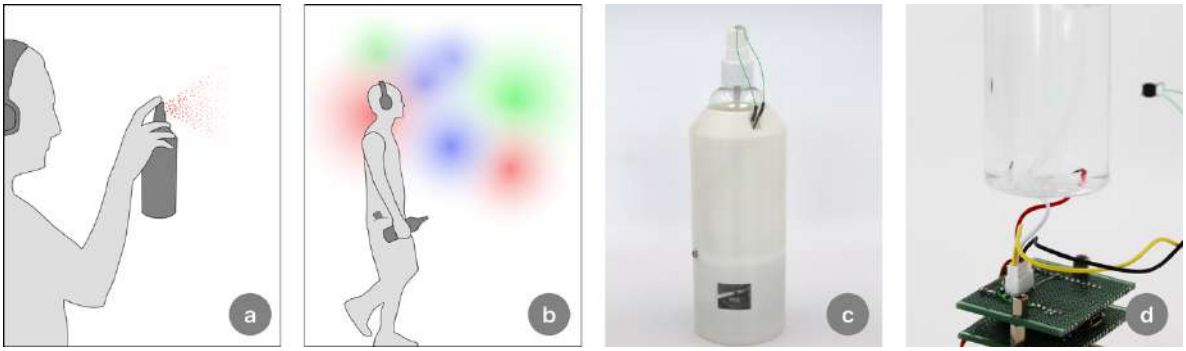

Figure 1: SoundMist is a spatial auditory system that users can spray sound in the space. (a) Locating sound by spraying the liquid. (b) Different sounds are diffused and mixed in a space. (c) Spray prototype of SoundMist. (d) Inner structure of prototype.

ABSTRACT

We introduce a novel method called 'spraying sound' for immersive auditory and spatial experiences. Our prototype SoundMist disperses sound into the surrounding space, enhancing immersion and spatial perception. Through user tests with 11 participants, we demonstrate the effectiveness of this approach in enriching the auditory experience and expanding possibilities for spatial auditory interactions. This research opens up opportunities to explore immersive spatial experiences with sound and makes a contribution by proposing a novel method of sound-space interaction through a system that sprays sound in a spatial context.

CCS CONCEPTS

• **Human-centered computing**; • **Human computer interaction (HCI)**; • **Interaction devices**;

KEYWORDS

Spatial auditory experience, sound interaction

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1 INTRODUCTION

Numerous explorations have aimed to expand auditory experiences into multi-sensory realms, incorporating visual [1], haptic [2], and behavioral elements [3] to enhance immersion. Among them, there were endeavors on spatial experience augmented auditory systems, including soundscapes [4], sound zones [5], and 3D audio [6] [7] which opened up potential for interaction with auditory environments in a spatial setting [8] [9]. Moreover, such efforts have explored physical interactions within sound environment, such as adjusting music [10], perceiving spatial awareness [11] [12], and locating sound sources [6] [13] [14]. In this context, inspired by the practice of air scenting, we introduce the concept of 'spraying sound' as a novel multi-faceted experience by diffusing liquid in the space, generating sound that lingers and gradually disappears (Figure 1a). In this method, sound is dispersed in a space, like a gradually fading fragrance, thus creating a unique auditory environment (Figure 1b). This concept contributes to immersive spatial interactions within the field of sound-space interaction.

2 SOUNDMIST

The SoundMist system comprises a spray prototype, an Android mobile app, and a Bluetooth headphone, all connected wirelessly to a server computer. Users interact with the spray prototype to transmit real-time sound identity information, while carrying the mobile app to share their location with the server. With information, the server calculates and delivers the sound to user's headphone, enabling an immersive auditory experience.

2.1 Spray prototype & Android application

The spray prototype (Figure 1c) utilizes the conductivity of the liquid to determine the sound's identity. In the spray, two wires connected through electrolyte enable the flow of different electric

Table 1: Interview questionnaire and results in five-point Likert scale

Questions	Average ± Std.
Q1. Is the concept of spraying sound novel to you?	4.64 ± 0.64
Q2. Did you feel like you were spraying sound using this prototype?	3.18 ± 0.94
Q3. Did you perceive the sound as floating in space and yourself moving around in that space?	3.82 ± 0.83

current, upon electrolyte's conductivity (Figure 1d). The Microcontroller unit (MCU) recognizes the electrolyte's identity upon the current flowing in, and assigns the corresponding sound. 3 baking soda solutions with concentrations of 0%, 0.3%, and 5% are used as electrolytes, representing pre-recorded funk band performances of drum/bass, piano, and guitar sounds, respectively. Funk music is chosen due to its rhythmical characteristic, that well fits to physical behavioral aspect of SoundMist. The MCU contains built-in Bluetooth chip (CC2540) for Bluetooth Low Energy (BLE) 4.0 communication. When the spraying action is detected by the button on the prototype's top, real-time sound identity information is transmitted to the server computer via BLE. The Android application, installed on user's phone, transmits real-time GPS information to the server computer using Wi-Fi. During system usage, the mobile phone remains in the user's pocket and continuously tracks user's position.

2.2 Server computer

The server generates an invisible sound circle with an 8-meter radius at the user's location when they spray the liquid. The volume of the corresponding sound decreases as the user moves away from the circle's center, becoming inaudible outside the circle. The circle gradually reduces its volume and disappears after 180 seconds, mimicking the dispersal of the fragrance. The radius and duration of the sound circle are determined based on 3 pilot studies. The volume of each instrument is determined by the user's location and the distance to each sound circle of that instrument, following specific rules:

- If the user is not within any associated sound circle, the volume of the instrument is set to zero.
- If the user is within one sound circle, the volume is determined by an inverse proportion to the distance from the user to the circle's center. The volume (V) is calculated based on the maximum volume of circle when generated (Vol_M), the distance from the user to circle's center ($d < 8$), and the time elapsed after circle is generated ($t < 180$) as follows:

$$V = Vol\_M \times (8 - d)/d \times (180 - t)/t$$

- If the user is within multiple sound circles, the volume of that instrument is determined by selecting the maximum value among the independent volumes heard from each sound circle, which follows the same rule as Rule 2.

The server sends volume of each instrument to the Bluetooth headphone, playing ensemble with the specified volumes for user.

3 USER STUDY

Individual user studies involving 11 participants (aged 23-28, male: 7, female: 4) were conducted to assess the expansion of auditory experiences into spatial domain, in a 30m by 55m outdoor field. Participants' consent forms were collected in advance. Participants used the prototype to emit mist while wearing Bluetooth headphones and moving around the field. They were told to freely changed the liquid inside of prototype to change the instrument. After the experiment, participants responded to three questions (Table 1) using a Likert scale (1-5) and provided reasons for ratings. Participants also suggested potential applications of SoundMist.

3.1 Results

In summary, SoundMist offers a novel expansion of auditory experience into the spatial domain, according to the high scores in Q1 and Q3 (Table 1). However, the lower score in Q2 suggests that the interaction of spraying sound did not fully convey the intended sensation to the users. According to interviews, participants gave high scores in Q1 because they have rarely heard concept of spraying sound. Positive responses for Q2 were attributed to the sound playback when spraying, while negative responses highlighted that sound remained stationary when wind disperses liquid particles. High scores in Q3 were related to the perception that the sprayed sound remained over time and created a sense of spatial presence when combined with other sounds. There were also suggestions to improve the perception of sound location by adapting 3D sound. They also explored potential application areas including multi-sensory experiences with perfumes, interactive music sharing devices at festivals, and auditory descriptions of artworks at exhibitions.

4 CONCLUSION

This research contributes to presenting the concept of 'spraying sound' as a novel sound-space interaction, and utilizing it to expand auditory experiences into spatial dimensions. However, limitations such as the need for improved sound location indication are identified, suggesting avenues for future development. The SoundMist system bridges sound and space, offering immersive and sensory-rich experiences, with potential for further advancements in spatial sound design and multi-sensory engagement.

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