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NOISE IN THE HIGH-TECH CITY: LISTENING TO SHENZHEN THROUGH A PARTICIPATORY PHONE-BASED APP

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ABSTRACT

How can we enhance our understanding of dense, large, rapidly developing megacities by listening to them? Given that the city comprises different strata of technologies, classes, industries, businesses, transportation modalities, and natural features, Shenzhen offers an example of a fast-changing, large urban space of complex sonic environments. This project develops what we call a "distributed" system through which untrained users, using their personal mobile phones, listen to and record Shenzhen. This participatory approach to understanding the city through sound allows us to collect qualitative data from untrained participants. In two selected locations, a green park and a science park, we prompt them to add contextual photos and verbal tags to what they record into the database. In this paper, we introduce a unique creative method of listening to the city via a distributed system that utilizes ubiquitous mobile technology in the contemporary city of Shenzhen. We present a pilot system that we developed and the results of a small-scale user study, which contributed empirical insights into reflective dimensions of Shenzhen's soundscape and demonstrated an effective approach by public participation and human-computer interaction.

Keywords: *urban soundscape, megacities, citizen science, human-computer interaction, mobile technology*

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1. INTRODUCTION

This project is inspired by the "noisy" but rich sound environments in megacities, such as Shenzhen, which have a profound and complex influence on people's everyday life. The perceived sound environment defines a "soundscape", an acoustic equivalent of landscape [1]. In this project, we aim to, by designing and using a participant-centered interactive system, capture the qualitative aspects of human soundscape perception, which extends the one-dimensional measurement of "noise pollution level". Central to our research is the "human-centered" perspective embedded in the soundscape concept. During the past century, data-driven deep learning methods have been successful in computational acoustic scene analysis, leading to meaningful contributions to large-scale noise monitoring and management in New York City [2]. However, these methods mainly rely on object-centered semantic descriptions [3] for source, event, and scene classifications. Our study instead wants to highlight the nuanced qualitative aspects of urban sound perception, centered on subjective on-site experience of citizens, which could extend our understanding of the dynamics between soundscape and urban lives, and motivate future development of human-computer collaborative soundscape research.

Therefore, this study adopts the citizen science paradigm [4] for participatory sound data gathering and analysis. Instead of conducting purely laboratory-based perceptual experiments, our study invites human participants to actively contribute to the process of field recording, collection of visual information, and verbal annotation by using our custom-designed web-based mobile app. The collected data are then displayed, as an interactive sound archive, on a web interface designed for home computers. The mobile app and the sound archive interface, together with human users, form a distributed

human-computer system that monitors and digitalizes urban acoustic environments and associated experiential qualities.

Through this research, we investigate how to establish a human-computer collaborative platform that utilizes ubiquitous mobile phones for the monitoring and assessment of complex soundscapes of megacities like Shenzhen. From a human-centered perspective, we also investigate how such a platform could facilitate users' expressive and creative engagement with their sonic environments. In this paper, we take the first step by developing a mobile- and computer-based system prototype and studying how users engage with and assess soundscapes in two distinct and interconnected locations that characterize Shenzhen.

In the following sections of this paper, we present the background, the system design, a three-stage user study, quantitative and qualitative analysis and results, discussions of the findings and the conclusion.

2. BACKGROUND

Sonic environments in megacities are shaped by rapid urbanization, dense infrastructure, and diverse human activities, and understanding them requires more than conventional noise monitoring. The concept of the soundscape—originally introduced by Schafer [5] to describe the acoustic environment as perceived and experienced by humans—offers a valuable lens for understanding how sound shapes our relationship with urban spaces. Unlike conventional noise metrics that reduce sound to decibel levels, soundscape research considers environmental sound as a resource that needs rational utilization, protection, and enhancement [1].

In both noise control and soundscape management, citizen science [4] has been increasingly adopted as a way to involve the public in data collection, perception studies, and local decision making. By engaging residents as active contributors rather than passive subjects, participatory approaches enable the collection of context-rich, situated knowledge that complements technical measurements and informs inclusive urban sound planning and design. Participatory sensing, leveraging information technology infrastructures, uses human users with GPS-equipped smartphones as sensors in data collection and evaluations [6]. This paper's approach has been inspired by many related works combining the soundscape approach with citizen science paradigm for participatory exploration and evaluation of urban sonic environments.

The Hush City mobile app [7], designed for participatory identification and evaluation of urban quiet areas, allows for in situ mapping of identified areas and the collection of associated mixed data. These data are multi-dimensional, mixed by field recordings, noise level measurements, pictures and user verbal feedback. The app, over years, has empowered local communities to play an active role in participatory processes of quiet areas evaluation and planning.

While the Hush City app emphasizes its impact in participatory planning and protection of urban quiet areas, other works that leverage mobile technology and public participation have approached soundscape research through a cultural or artistic lens. For example, the Locate Your Sound project [8] centers on archiving and accessing soundscapes as intangible cultural heritages using digital tools (web + mobile interface). The Locate Your Sound (LYS) platform was developed to archive, browse and access soundscapes. In the two crowd-sourcing initiatives, the web interface encouraged users to compare the recorded soundscapes with their memories and expectations, while smart panels promoted exploration.

Another work, UrbanRemix [9], positioned itself in an artistic exploration and rediscovery of urban spaces through the lens of locative media, music, and interaction design. UrbanRemix was a platform consisting of mobile-device applications and web-based tools to facilitate collaborative field recording, sound exploration, and soundscape creation. The evaluation of the platform was carried along its use in workshops, festivals, and community events, focusing on its ability to enable public creative expression.

Our project connects critical reflection and creative composition with site-specific user-contributed sound data, enabling people to document, reinterpret, and critically engage with urban sonic environments.

3. SYSTEM DESIGN AND IMPLEMENTATION

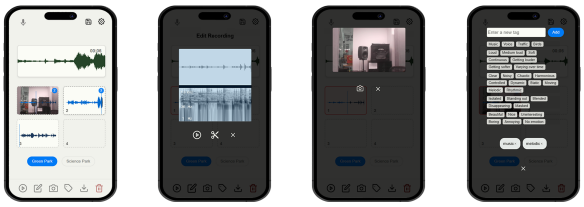
Combining the soundscape and citizen science approach, this paper proposes a system for participatory sensing of the complex sonic environments of megacities. The system consists of two main components: a web-based mobile app for recording and collecting contextual and personal information of sonic environments; and a computer-based interface for exploring the user-contributed sound archive, a collaboratively built multimedia database of recordings.

Using this system, we invite users to two stages of

participation: field recording, and soundscape exploration and creation. In Sections 3.1 and 3.2, we present the design and implementation of a prototype of the system. In this prototype, the mobile and computer-based interface were not connected by a cloud server, and users were instructed to save data locally and transfer their data to our lab in person.

3.1 Mobile Recorder

This section introduces the first component of the system: a web-based mobile recorder designed to document soundscapes with multimedia contexts. The conceptual model of the mobile recorder defines a soundscape as a collection of four representative sounds, each combined with contextual and personal annotations in the form of photos and verbal tags. Fig. 1 illustrates the user interaction flow within the mobile app. At each location, the user selects a predefined location tag (green park or science park) before beginning field recording. The mobile interface is structured to allow a multidimensional documentation of in situ soundscape perception: users are provided with four empty slots, each intended to capture a distinct sound that contributes to the overall sonic environment. Each slot supports a 30-second audio recording, accompanied by a photo and descriptive verbal tags. This design aims to prompt users to actively engage with and reflect on the auditory characteristics of their surroundings.



(a) (b) (c) (d)

Figure 1: UI of mobile recording app. (a) Main UI (b) Sound editor (c) Camera (d) Tagging system.

Two audio visualizations were incorporated into the design to enhance user interaction. During recording, a scrolling waveform visualization provides real-time feedback on the temporal patterns of the recorded sound (Fig. 1a). In the sub-panel for sound editing (Fig. 1b), a spectrogram visualization is displayed to assist users in examining the frequency components of their recordings.

The app's tagging system provided six predefined categories of verbal tags, along with a free-text entry for any user-specified tag regardless of category. The predefined categories and tags, inspired by sound descriptors for non-experts [10] and soundscape descriptors [11] are as follows:

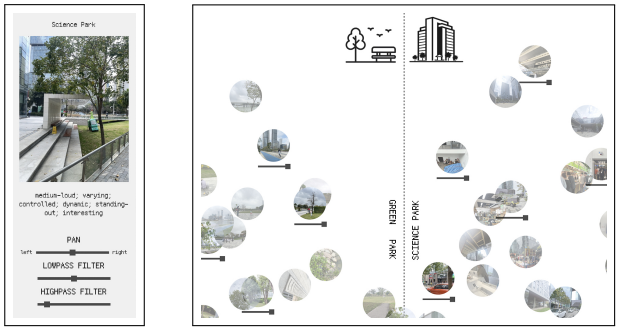
- Source Type: Music, Traffic, Birds, Voice,
- Volume: Loud, Medium loud, Soft, Getting louder, Varying over time, Getting softer, Continuous,
- Texture: Clear, Noisy, Chaotic, Harmonious, Controlled, Dynamic, Static, Moving,
- Music: Melodic, Rhythmic,
- Context: Isolated, Standing out, Blended, Disappearing, Masked,
- Pleasantness: Beautiful, Nice, Uninteresting, Boring, Annoying, No emotion.

3.2 Creative Player for Sound Archive

The creative player is a computer-based interface designed for interacting with the sound archive, a growing collection of user-contributed soundscape recordings. The sound archive functions as a dynamic database of sounds with associated metadata, including GPS locations, verbal tags, and contextual photos. This user-contributed database forms the foundation for interactive exploration. While the mobile recorder focuses on documenting in situ soundscapes, the creative player enables users to explore, rearrange, and reinterpret these recorded sounds in a reflective and expressive manner.

The design of the sound archive player emphasizes open-ended interaction. As shown in Fig. 2, collected recordings are visually arranged on a 2D canvas (Fig. 2b), categorized by location (e.g., green park or science park) and represented by circular thumbnails that include the associated photo. Users can freely browse and listen to the recordings by clicking on them—each click selects or deselects a recording. For every selected sound, an individual volume slider appears, allowing users to layer multiple recordings and adjust their levels independently.

The left panel (Fig. 2a) displays contextual information about the most recently selected recording, including its location, photo, and user-generated verbal tags. Below, users can apply basic sound editing tools—panning, low-pass filtering, and high-pass filtering—to the active sound, which invite users not just to replay recordings, but to actively reshape them. In addition, the circular thumbnails can be dragged and repositioned, encouraging users



(a) (b)

Figure 2: UI of the computer-based creative player. (a) Metadata of the selected recording, panning effect and filters (b) canvas for free exploration of the recordings.

to creatively reinterpret the spatial and experiential qualities of the urban soundscape. Through these interactions, the creative player serves not only as a listening tool but also as a space for reflection, composition, and critical engagement with the sound environment.

4. USER STUDY PROCEDURE

This section details a small-scale user study conducted within one day in Shenzhen. This user study investigates how participants engage with the mobile recording app and creative player system, and how they reflected on and reinterpreted the representative sonic environments of their city in the process. A green park and a science park (Figure 3) were selected as study locations, as they epitomize distinct yet interconnected urban dynamics of Shenzhen—one representing natural, recreational spaces, and the other reflecting high-tech, work-oriented environments. Seven participants were instructed to use with the system to explore and document the sonic environments at both sites.

The user study was conducted in situ and in a laboratory setting, consisting of three stages:

4.1 Stage 1: In Situ Sound Exploration and Collection

Participants explored two distinct urban environments—a green park and a science park—using the mobile recorder described in Section 1. At each location, they were instructed to:

(a) (b)

Figure 3: User study locations. (a) Green park: Shenzhen Talent Park, (b) science park: Shenzhen Software Industrial Base.

- Record four sounds that they felt best represented the sound environment. Audio recording has a 30-second limit, and users can trim the recorded sound in the editor view.
- Take a photo to each recorded sound using the app's camera view.
- Annotate each sound with descriptive verbal tags using the app's tagging system.

After completing these steps for both environments, participants were asked to complete a questionnaire reflecting on their experience of sound collection and documentation. This stage aimed to capture participants' subjective selection and perception of characteristic urban sounds within different environments.

4.2 Stage 2: Group Discussion

After completing the fieldwork and questionnaires, participants were invited to a meeting room for a group discussion. The discussion leader asked specific questions about what emotional relationship the participants have with sounds in big cities. The discussion provided qualitative insights into collective and individual experiences, helping to frame the next phase of the study.

4.3 Stage 3: Lab-Based Sound Exploration and Composition

After the group discussion, participants proceeded to an interactive listening and organization session in a laboratory setting individually. Using the computer-based creative player detailed in Section 2, they engaged with the multimedia sound archive.

This stage was conducted as a semi-structured interview where participants were guided through a series of interactive tasks:

1. Free Exploration: Participants were given time to freely interact with the interface, playing back sounds individually or in combination. They were asked to describe their actions and perceptions.
2. Sound Arrangement Task: Participants were instructed to rearrange sound elements on the screen in a meaningful way and explain their organization strategy.
3. Sound Mixing Task: Participants were asked to create their ideal city soundscape by mixing different recorded sounds. They then explained their choices and the key ingredients of an ideal urban sound.
4. Reflection: Participants reflected on their experience of listening to Shenzhen's urban sound environment, how the recording and playback interfaces influenced their perception, and what symbolic sounds define Shenzhen.

This stage aimed to explore how users interpret, structure, and interact with urban sounds in a digital space while providing insights into their perception of Shenzhen's sonic identity.

5. DATA ANALYSIS AND RESULTS

Quantitative and qualitative analysis were conducted to evaluate the user study, aiming to answer two questions: 1) how could the developed system support participatory assessment of complex urban soundscapes in Shenzhen, and 2) how could the system facilitate users' expressive and creative engagement with their sonic environments from a human-centered perspective.

5.1 Data Collection and Analysis

Multimedia data were collected throughout three stages of the user study.

- Stage 1 : Participants used the mobile app to record environmental sounds, accompanied by metadata including date, time, and GPS location. They also submitted photos and short verbal tags for selected recordings. Additionally, participants completed a questionnaire about their on-site perception and experience.
- Stage 2 (Group Discussion): A group discussion was held and documented by audio recording.
- Stage 3 (Creative Composition): Data collected included audio recordings of semi-structured interviews, screen recordings of participants' interactions with the creative player, their resulting sound compositions, and video recordings of participant behavior during this phase.

Some data were lost due to user error. Specifically, 48 out of 56 field recordings were successfully retained for analysis, all of which were accompanied by photos; 37 of these 48 recordings also included verbal tags. All seven distributed questionnaires were completed and returned.

This paper focused on two main sources of analysis: 1) quantitative analysis of questionnaire responses, in combination with participants' verbal tags associated with the recordings, and 2) qualitative analysis of interview data, based on transcripts derived from audio recordings of Stage 3.

Our analysis was organized around four core themes: 1) situated listening and perception, 2) motivations and meaning-making of recorded sounds, 3) comparative reflection of overall preference on two environments, and 4) expressive and reflective engagement with the system.

5.2 Participants

Seven participants (5 female, 2 male) took part in the user study. Most participants (85.71%) were aged between 18–25, with one participant in the 31–40 age range. Two participants (28.57%) currently live or have previously lived in Shenzhen.

5.3 Results

5.3.1 Situated Listening and Perception

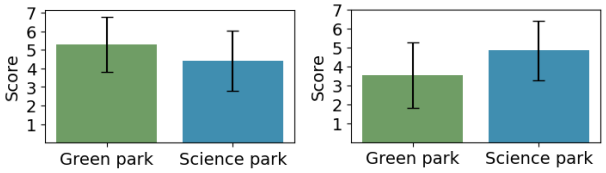
This section presents findings on what participants heard and noticed in the moment, and their overall impression of the soundscape. Participants' auditory attention is reflected in the submitted verbal tags. These tags reveal shared patterns across sites: voices were the most frequently captured sound sources; science park recordings were more often described as noisy, chaotic, and medium-loud, with sounds tending to blend into the environment. In contrast, green park recordings were frequently described as soft, clear, and beautiful, with sounds that stood out more distinctly. A summary of tag frequencies is presented in Tab. 1. Only tags mentioned at least three times at either location are included.

Participants' subjective impressions of the sonic environment were assessed through four questionnaire items

Table 1: Frequency of selected tags across 2 sites.

CATEGORY	TAG	SCIENCE PARK	GREEN PARK
Source Type	Voice	**5**	**6**
	Traffic	1	**3**
Volume	Continuous	5	3
	Medium-loud	**6**	3
	Soft	0	**4**
Texture	Noisy	**7**	3
	Chaotic	**5**	1
	Clear	1	**4**
Pleasantness	Annoying	**3**	1
	Boring	**3**	1
	Beautiful	0	**4**
	Nice	2	3
Context	Blended	**6**	1
	Standing-out	1	**3**

on a 7-point Likert scale, evaluating overall sound quality and how characteristic the recordings were for Shenzhen. As shown in the bar graphs in Figure 4, the green park received higher ratings for sound quality, while the science park recordings were considered more characteristic of Shenzhen.



(a) (b)

Figure 4: Participants' subjective ratings of overall sound quality (a) and characteristic nature (b) of the recordings. Error bars represent standard deviation.

5.3.2 *Motivations and Meaning-making*

This section analyzes participants' motivations behind their sound selection and how they interpreted meaning in the process of recording. In response to the item "Did you have a specific idea of what to record before you started, or did you decide spontaneously?", most participants reported making spontaneous decisions on-site, particularly in the science park. Specifically, 86% of participants chose sounds spontaneously in the science park, while 14% had a general expectation in advance. In the green park, spontaneous decision-making was still common but less dominant: 57% chose sounds spontaneously, whereas 43% reported having general expectations beforehand.

Participants' motivations for selecting specific recordings were further examined through a multi-choice question asking what influenced their choices. A bar graph of response frequencies is shown in Fig. 5. In the green park, the most frequently selected reasons were that the sounds were *typical of the place* and *quiet/subtle but meaningful*. In the science park, participants were more often motivated by the sounds being *annoying or disturbing*, in addition to them being *typical of the place*.

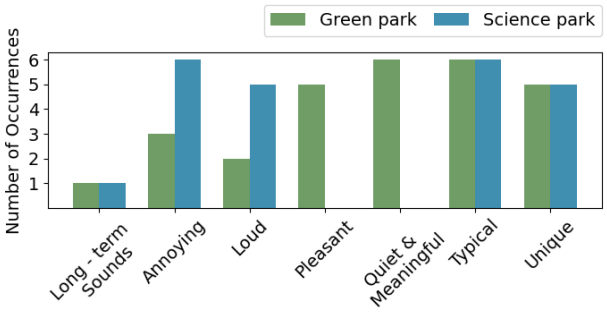


Figure 5: Frequency of participants' selected reasons (multi-choice) for choosing specific sounds in each location.

5.3.3 *Comparative Reflection of Preference*

In Stage 3 (Section 4.3), participants reflected on their comparative assessment of both locations after listening to the sound archive, prompted by the question "Which recording location is more interesting to you". 40% of the participants chose the science park in response. Some of the reasons given for this were: sounds in the science park have "greater unpredictability and complexity", and imply "greater diversity of people's activities". By contrast, 30% commented that the green park was more interesting to them because the sounds of the science park were more "repetitive". One participant mentioned that sounds in the "science park were more regular and predictable", and that such sounds were "too common in everyday life". The re-

maining 30% of participants found the sound of both locations to be equally interesting.

5.3.4 Expressive and Reflective Engagement

This section presents results concerning participants' expressive and reflective engagement with the system.

Regarding the user experience of the mobile recorder, more than 50% of the participants agreed that the app gave them an opportunity to explore and discover unnoticed sounds in their lives , and motivated them to "deliberately look for some unique sounds at hidden corners". 30% of the participants believed that the 30-second limit for each recording was short and hence convenient for users to remember the recorded sounds. 40% participants mentioned that the mixture of photo and audio is novel format that help users remember the process. One participants noted that the timely manner of audio recording, photo taking, and tagging enhanced their memories of the whole process. One participant suggested that the editing function is non-essential because the 30-second limit allowed them to redo the recordings in easily in case they were not satisfied with the recorded sounds.

Regarding the user experience of the creative sound archive player, 30% of the participants commented that the interface had a high degree of freedom for exploration and manipulation. 40% participants said that the associated thumbnail photos helped them understand "why the contributor chose this sound at that time". 85% participants mentioned that the interface was "intuitive and easy-to-use" and that "there is nothing to improve about this interface".

During the task of constructing an "ideal city sound" on the creative sound archive player, more than 90% of the participants agreed that an essential element in the construction of an ideal city sound is the "people", in other words, human activities. Two participants pointed out that the interactions "within people and between people and their environment" were reflected by the mix of "sound of the nature and sounds produced by people in the particular environment".

85% of the participants emphasized the balance between the ingredients of nature, people, and technology in the ideal city sound mix. 30% of the participants associated isolated "traffic noise", "construction noise", or "noise" with negative words such as "uncomfortable" and "low quality". Nevertheless, participants generally agreed that the ideal city sound mix should not only have sounds of the nature which were "relaxing and enjoyable", but also include the sounds of human activities and technology. One participant mentioned that a city "has to have some traffic sounds", but these traffic sounds "should not be more than the nature's sound or humans' sound".

Regarding participants' general impression of Shenzhen's symbolic sounds, 40% of the participants responded with "high efficiency", "fast-paced", and "work". 40% of the respondents said that Shenzhen's urban sounds are generally "predictable', "monotonous" and "repetitive".

6. DISCUSSIONS

From data analysis and results, we collected insightful participant feedback on the ideal ingredients and composition of the holistic urban soundscape. As reported by the participants, the key ingredient of ideal city sound is the sound of human activities. In addition, an ideal city sound composition must maintain a balance between the contributions of nature, people, and technological infrastructure. The "noise" of the technological infrastructure should not be removed, but exist in a way to not mask the sounds of nature or human activities. This balance in soundscape composition implied citizens' ideal of Shenzhen's sonic identity, where the existence of technology is not to be ignored, but rationally incorporated.

Regarding participants' creative and reflective engagement with the proposed system, the mobile app motivated people to pay attention to subtle sounds and consciously identify sounds from the usually unnoticed auditory background. The sound archive player allowed for playful interaction and reflection on the collective abstraction of city sound. The interface was intuitive and easy to use for non-experts in the sound domain, which is meaningful to support broader public engagement in exploring and evaluating urban soundscapes.

Compared with the existing platforms and mobile app for participatory soundscape research, our system innovates the conventional soundscape representation by designing a digital canvas for reflective, expressive and creative user engagement with the digitized urban soundscape. While the Hush City app, LYS system, and UrbanRemix platform utilized the GPS-based sound map for soundscape representation, our sound archive player allowed for free exploration and manipulation of multimedia recordings based on the user-contributed database. In our interface, users could visually reposition and compose sounds according to their individual preference or unique expression of desired and principles.

Grounded in soundscape research and citizen sci-

ence, this study combines fieldwork, lab-based evaluation, human-computer interaction, and public participation to contribute empirical insights into the situated, affective, and reflective dimensions of participatory soundscape assessment. Our findings show how a human-centered digital platform can support situated listening, motivate personal and context-based meaning-making, and foster expressive engagement with the sonic environment. Based on this prototype and user study results, we will improve the platform by enabling online social interaction to connect users and reach out to a broader public for participatory soundscape exploration and recreation.

7. CONCLUSION

By enabling participants to actively document, interpret, and creatively engage with urban sonic environments both in situ and in a designed digital space, our system contributes to soundscape research by foregrounding subjective and multidimensional soundscape perception. It also supports citizen science by fostering participatory, expressive, and reflective interaction with everyday sound, encouraging new forms of environmental awareness and engagement. The project opens new avenues for investigating dense megacities by listening to them via a participatory, distributed system.

8. ACKNOWLEDGMENTS

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