Music in the Air: Creating Music from Practically Inaudible Ambient Sound

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Abstract. *Music in the Air* is a pioneering system that generates real-time music from the "theoretically audible but practically inaudible range" (TAPIR) ambient sound, opening new possibilities in music composition. The system captures and analyzes the ambient sound and utilizes its TAPIR portion to generate musical notes in a MIDI format. It has proved to function successfully at an audiovisual art exhibition, showing the potential to blur the line between natural and artistic by unveiling hidden melodies within "silence" for inspiring compositions. In addition to its musical significance, this paper introduces the system focusing on the mapping strategy for MIDI note generation. The demo at the conference will showcase its initial implementation and a newer version with more advanced features supporting versatile musical mappings.

Keywords: Real-time music generation, ambient sound, spectral analysis, TAPIR (Theoretically Audible but Practically Inaudible Range), MIDI, musical composition, musical sonification

1 Introduction

Throughout history, humanity has continuously sought inspiration from the world around us to create music. While natural soundscapes have often served as a source of creative influence, the concept of generating a new piece of music from hardly audible portions of the ambient sound is relatively unexplored.

In this context, we introduce *Music in the Air*, a system for real-time music generation from the almost inaudible high-frequency part of the ambient sound, thereby unveiling the melodies hidden within "silence." The system provided the music (or a monophonic melody) for an audiovisual art exhibition with the same title held at *Gallery Insa Art*, Seoul, Republic of Korea, in May 2023, which was presented by the authors (see Fig. 1).

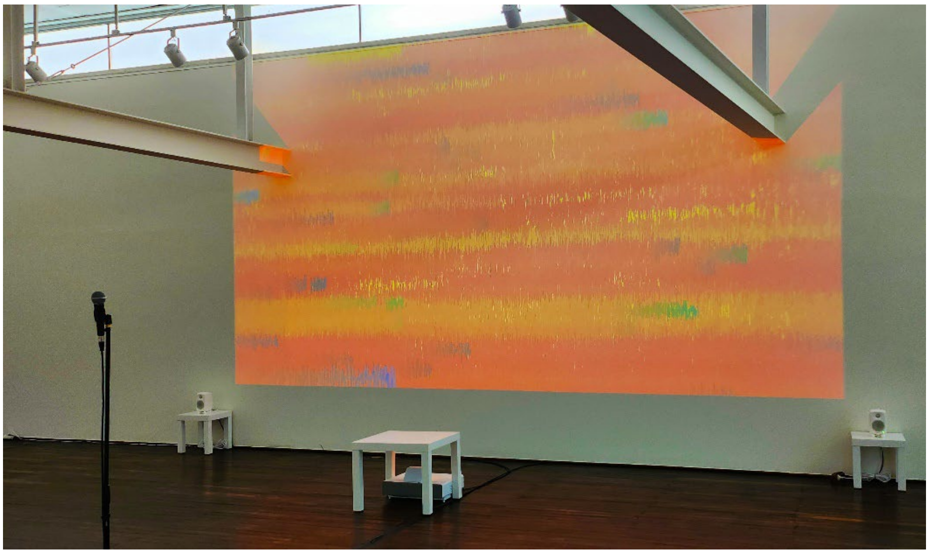

Fig. 1. Photo of *Music in the Air* exhibition held at *Gallery Insa Art* in May 2023.

The motivation behind creating new music from the hardly audible part of the ambient sound of a space lies in the desire to push the boundaries of music composition and foster a deeper appreciation for the intricacies of sound; by extracting, analyzing, and transforming the inaudible ambient sounds, we aim to unlock a new realm of musical possibilities, allowing composers to explore uncharted auditory landscapes. Not only can this be understood as an effort to extend the range of human audibility, but also a unique and innovative method to generate original sounds or compose new music based on something that is not audible.

This paper introduces a brief technical background to the practically inaudible audio, describes not only the overall structure of the system but also the technical details of the implementation and the demo scenarios, and discusses its musical significance and possible future enhancements.

2 System and Methodology

Fig. 2 illustrates the overall setup and the signal flow of the system. Here, only the TAPIR components of the captured ambient sound get analyzed in the frequency domain to provide musical information.

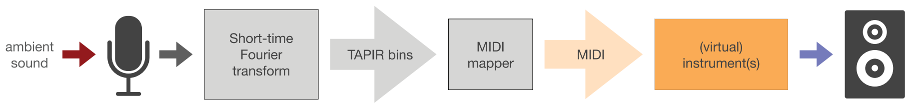

Fig. 2. System Overview.

2.1 (In)audible Range

Human audible frequency range spans from 20 Hz to 20 kHz, theoretically. However, in reality, very few individuals possess the ability to hear sounds at the extreme ends of this. Several factors, including age, genetics, and the environment (e.g., exposure to loud noises over time), can affect an individual's hearing sensitivity and narrow the practical audible range. In practice, the upper limit of the audible frequency range at average volumes is around 18 kHz for most adults – including those in their 20s, which is lower than the theoretical value. As a result, we may call this marginal bandwidth in the upper end of human audible frequencies as the "theoretically audible, but practically inaudible range" (TAPIR), as suggested in [1].

2.2 Audio Capture and Spectral Analysis

Notably, with a sampling rate of 44.1 kHz or above and typical acoustic transducers (i.e., ordinary microphones without ultrasound features) covering a frequency response range up to above 20 kHz, most computers and smartphones can capture and analyze sounds in this TAPIR range with little problem. Understanding the existence of these sounds, which we can hardly hear but that machines easily can, is crucial for designing audio experiences and related technologies for *Music in the Air*. For the exhibition, we used an SM58 by Shure [2], one of the most common microphones.

The spectrum of the captured audio signal is then analyzed in real time using the fast Fourier transform (FFT) function of the minim library [3] in the Processing programming environment [4]. Depending on the size of the FFT, the "resolution" (or the interval between adjacent frequencies) and the number of spectral components (or frequency bins) of the resulting spectrum may vary. For example, with the FFT size of 1024 and the sampling rate of 44.1 kHz, we get about 94 bins within the range from 18 to 22.05 kHz at the interval of 43.07 Hz between the adjacent frequency bins of FFT.

2.3 MIDI Mappings

For the actual generation of music/sound (i.e., something we can hear), spectral analysis results must get utilized to determine the elements of musical notes or parameters for sound synthesis. In the exhibition, real-time spectrum information was "mapped" to generate musical notes in a MIDI message format, i.e., pitch by note number, duration by Note On and Note Off (or onset and release, respectively), and the type of the instrument by MIDI channel (or other program messages, if necessary), as briefly described below:

Pitch. To determine the pitch of the musical notes to generate, we should establish a rule that maps selected frequency bins from the FFT result to musical notes, which has the most significant impact on the overall impression of the result. Depending on the type of musical characteristics in mind, the mapping rule can change differently, involving questions on musical texture (i.e., monophonic vs. polyphonic) and scale (i.e., limited choice of pitch).

Onset and Release. In the case of real-time generation, the duration of a MIDI note can only be determined as the interval between the reception of Note On and Note Off messages. For this, the loudness level of each frequency bin of interest needs to be monitored continuously to detect the moment of onset and release. Note that, in addition to adjusting the threshold levels for onset and release detection, we may need to check/control the gain level of the microphone input signal.

Instrument. Generated note information is sent to any instruments, either hardware synthesizers or virtual instruments, that support MIDI connection. Multiple instruments can be connected simultaneously, each playing a different melody.

3 Demo

Music in the Air is a work in progress and continues to evolve. As such, the demo will feature not only the original system used in the exhibition but also a newer version that provides a graphic user interface (GUI) that allows the user to choose the desired musical mapping scheme from various options. In addition, we will share our experience obtained through the design and development process of the system in detail, primarily focusing on the MIDI mapping rules.

As for the musical instrument, the demo will showcase several software synthesizers with different timbre and tonal characteristics, including those provided on macOS via *Logic Pro*, providing a chance to experience the effect of timbral change.

4 Conclusion

Music in the Air demonstrates the ability to generate musical information from the inaudible portion of ambient sounds, suggesting a new approach in musical composition that blurs the lines between the natural and the artistic. By expanding the boundaries of traditional musical sources and unveiling the hidden melodies within silence, composers can draw inspiration from the subtle and often overlooked soundscapes and gain a fresh perspective on the infinite possibilities within our sonic environment.

In addition to performing tests in various environments to develop a versatile but robust methodology and mapping schemes, future work will include the integration of the system into interactive and immersive musical experiences with novel and engaging performances in mind.

References

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