Real-time Measurement and Display System of 3D Sound Intensity Map using Optical See-Through Head Mounted Display

Yuta Kataoka
Waseda University
kataoka8894@akane.waseda.jp

Wataru Teraoka
Waseda University
tera-wata1129@fuji.waseda.jp

Yasuhiro Oikawa
Waseda University
yoikawa@waseda.jp

Yusuke Ikeda
Tokyo Denki University
yusuke.ikeda@mail.dendai.ac.jp

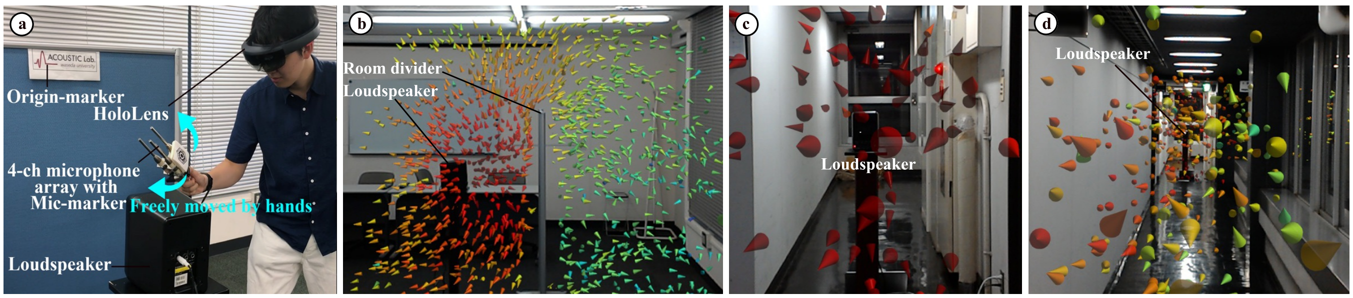

Figure 1: (a) Proposed real-time measurement and visualization system. (b) Visualized sound intensity map around a room divider (A vertex of cone represents the direction of sound intensity, and cone's color represents the level of sound intensity). (c) and (d) Sound intensity map of space in a corridor. The view points are 1.0 m and 12.0 m distant from a loudspeaker, respectively.

ABSTRACT

We propose a system of real-time measurement and visualization for three-dimensional (3D) sound field by using the optical see-through head mounted display (OSTHMD) with simultaneous localization and mapping (SLAM). By using an estimation of spatial mapping, the system achieves free movement of measurement positions in a broad area without multiple AR markers. Visualizing the 3D sound intensity of an entire room by the proposed system helps us to design the sound field within a space.

CCS CONCEPTS

• **Human-centered computing → Mixed/augmented reality**;

KEYWORDS

scientific visualization, acoustic imaging, sound intensity, mixed reality, augmented reality.

ACM Reference format:
Yuta Kataoka, Wataru Teraoka, Yasuhiro Oikawa, and Yusuke Ikeda. 2018. Real-time Measurement and Display System of 3D Sound Intensity Map using Optical See-Through Head Mounted Display. In *Proceedings of SA '18 Posters, Tokyo, Japan, December 04-07, 2018,* 2 pages.
https://doi.org/10.1145/3283289.3283358

SA '18 Posters, December 04-07, 2018, Tokyo, Japan

ACM ISBN 978-1-4503-6063-0/18/12…$15.00
https://doi.org/10.1145/3283289.3283358

1 INTRODUCTION

For our comfortable life, the sound environment has been continuously improved. To improve the sound environment, it is important to understand the sound field. Thus, many sound measurement methods have been established in its long history. Especially, in visualization of sound field, it is required to measure at many measurement points, because sounds spread across a broad area.

The physical quantities of the sound field are represented as a 3D scalar/vector field. In our previous researches, a real-time measurement and visualization system of a 3D sound field has been proposed and developed by using a video see-through head mounted display (VSTHMD) and AR markers [Inoue et al. 2016]. In the previous system, the AR markers were used to determine the global position of HMD with a camera installed at the HMD. In addition, another AR marker installed at the microphone was used to detect a relative position of the measurement point corresponding to the camera's position. By using this positional information, the 3D quantities of sound were superimposed on the measurement point in the HMD. However, because of limitation caused by distance between the camera and AR markers, the multiple AR makers for the camera's global position are required to visualize in a broad area [Inoue et al. 2018]. To address the noise problem and the acoustic design, it is desired to measure in a broad area because the sound spreads a long way with reflections, diffraction and transmissions.

In this paper, we propose a real-time measurement and visualization system for extensive sound field by using OSTHMD (Fig. 1). We use Microsoft HoloLens as OSTHMD. The spatial mapping of HoloLens allows us to superimpose the measurement results directly on the real space. This also enables a broad range of measurements without multiple markers. A visualized sound quantity in this paper is sound intensity [Inoue et al. 2017]. It is a stationary vector field representing the energy flow of sound.

2 SYSTEM OVERVIEW

The overview of our developed system is shown in Fig. 2. After obtaining a spatial map of the room with OSTHMD, an origin of the global coordinate system is determined by using an AR marker (Origin-marker). The Origin-marker helps to redraw the measurement data in the correct position regardless whether or not the spatial map is obtained. The position of another AR marker (Mic-marker) which is installed at a 4-ch microphone array is detected by a camera of OSTHMD. Since the positional relationships between the Mic-marker and the microphones are given in advance, the global measurement position can be calculated from the camera position obtained by the spatial map. The measurement signals of microphone array are recorded by a PC via an audio interface. The 3D sound intensity is calculated from 4-ch measurement signals in the PC by using the two-microphones method [Inoue et al. 2017]. In this paper, OSC (Open Sound Control) protocol [Freed and Schneider 2009] is used on UDP (User Datagram Protocol). PC sends packets of measurement results at 0.5 s interval. Each packet includes four float values that represent the direction of 3D sound intensity in local coordinates and its intensity level. Finally, the virtual 3D object of sound intensity is positioned at each measurement point by combining the transmitted 3D sound intensity data and its positional information in OSTHMD.

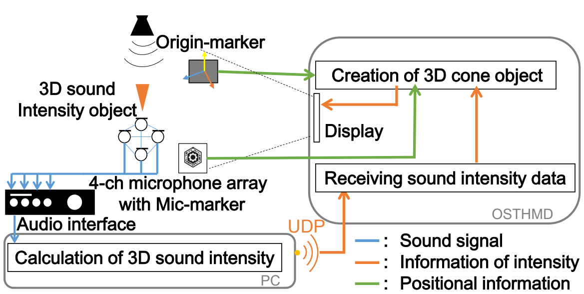

Figure 2: System overview. When a measured position and an intensity are transmitted to the OSTHMD, a virtual 3D object is shown on the display of OSTHMD.

3 VISUALIZATION

To show the broad measurement range of our developed system, we conducted two visualization experiments. The first experiment is measurement of the sound field diffracted by a room divider. The second experiment is measurement of the sound field in a corridor and a room. In both experiments, a loudspeaker was placed with white noise signal, its energy spreading equally over the entire frequency range. In the first and second experiments, sound intensities are measured at 1141 and 1165 points within an approximate time frame of one hour and two hours, respectively.

3.1 Sound field around a room divider

We measured and visualized the sound field around a room divider in front of a loudspeaker as shown in Fig. 1 (b). In the conventional system[Inoue et al. 2016], it is required to install several AR markers on both sides of the room divider to always detect the AR markers. In our proposed system, an AR marker is detected only once to determine the origin of global coordinate system. Thus, we can freely measure the sound field by obtaining the global position of OSTHMD from the spatial map. As shown in Fig. 3 (a), we can intuitively understand how the sound from the loudspeaker was diffracted by the room divider. Since the spatial map behind the room divider can be occluded, we can observe the sound field without confusion. Figure 3 shows how the room divider attenuated the sound by about 20 dB of intensity level.

3.2 Sound field in a corridor and a room

We measured and visualized the sound field in a corridor (Fig. 1 (c) and (d)). As these figures indicate, the sound intensity levels increased with approaching to the loudspeaker. Even if it is possible to obtain the spatial mapping, we can measure the sound field at a long distance from the Origin-marker which was installed near the loudspeaker. Figure 3 (b) shows that the sound from the loudspeaker spreads into an adjacent room. Since the entire sound field in the rooms or buildings can be measured by using spatial mapping, the proposed system can be a powerful tool to design room acoustics, evaluate sound insulation, etc.

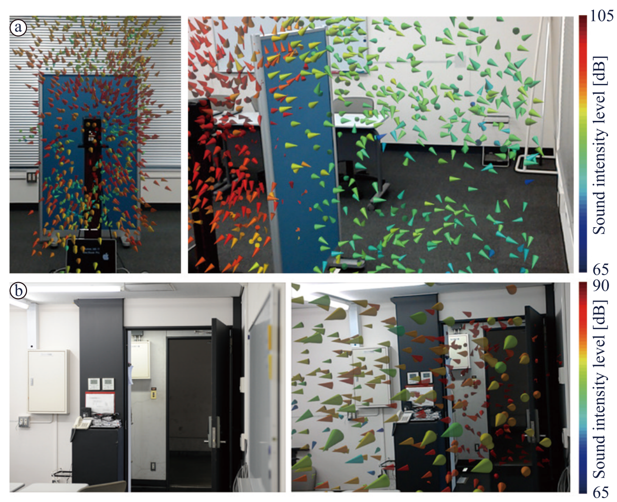

Figure 3: (a) Sound intensity map around a room divider. The figures on the left-hand side and right-hand side show sound intensity maps at the front and back of the room divider, respectively. (b) Sound intensity maps in an adjacent room. The left-hand side figures display general appearances of the measurement places. The right-hand side figure shows the intensity map of the sound incident to the room access.

REFERENCES

A. Freed and A. Schneider. 2009. Features and Future of Open Sound Control version 1.1 for NIME. In *Proc. 9th Conf. New Interfaces for Musical Expression (NIME '09)*.

A. Inoue, Y. Ikeda, K. Yatabe, and Y. Oikawa. 2016. Three-dimensional sound-field visualization system using head mounted display and stereo camera. In *Proc. Meet. Acoust*, Vol. 29. 25001. https://doi.org/10.1121/2.0000381

A. Inoue, Y. Ikeda, K. Yatabe, and Y. Oikawa. 2018. Visualization system for sound field using see-through head mounted display. *Acoust. Sci. Tech.* 40, 1 (Jan 2018).

A. Inoue, K. Yatabe, Y. Oikawa, and Y. Ikeda. 2017. Visualization of 3D Sound Field using See-Through Head Mounted Display. In *ACM SIGGRAPH 2017 Posters*. 34:1–34:2. https://doi.org/10.1145/3102163.3102243