PROCEEDINGS of the
23rd International Congress on Acoustics

9 to 13 September 2019 in Aachen, Germany

Visualization of Distribution of Room Acoustic Parameters by Using Mobile Robot

Masashi UEHARA[1]; Naoki ISHIKAWA; Shigeki OKAWA

[1] Chiba Institute of Technology, Japan

ABSTRACT

In this paper, we designed a robot system to generate a map which shows acoustic information in a room. A distribution of room acoustic parameters helps us understand acoustic environment; nevertheless it needs measurement of impulse responses at multiple points that are time-consuming. To visualize a distribution of room acoustic parameters with efficiency, we utilized a mobile robot with SLAM (which estimates the self-localization and environment map simultaneously). The mobile robot leverages self-localization to record measurement points and utilizes an environment map as a base to be plot acoustic information on. The robot repeats measurement of impulse responses and moving all over the room. We extract parameters from each impulse responses then conversion this parameters to color. Finally, we plot the color information at measurement points on the environment map. We examined how visualized a distribution of room acoustic parameters in an actual meeting room with enough accuracy. In result, the robot system generated maps of room acoustic parameters that are related to reverberation and speech clarity.

Keywords: Impulse response, Room acoustic measurement, Parameters mapping

1. INTRODUCTION

Measurement of impulse response (IR) leads to acquisition of room acoustic information that includes feature of reflection in a room. Some room acoustic parameters calculated from IRs are known to correspond to psychological quantities. These parameters help us to understand how reverberation sounds in the room. Moreover, necessity of acoustic measurements at multiple points is suggested (1). In some parameters, it is not possible to explain the acoustic characteristics of a room only by measurement results at one point representative of the room.

However, room acoustic measurements need a lot of manual operations, e.g. to move microphones and loudspeakers, record their positions, play measurement signal and record sound. Measuring at multiple points in particular is time-consuming.

Meanwhile, a robotic system is often utilized for measurement (2, 3). This is attributed to a robotic system can record self-location and sensed data on automatically. The improvement of ROS (robot operating system) and computer performance enable us to use navigation techniques easily.

Our goal is to improve efficiency of acoustic measurement by adding mobility to measurement equipment. It is meaningful to visualize the spatial distribution of room acoustic parameters for the purpose of showing the benefit of efficiency of measurement. Thus we proposed and developed a room acoustic parameters mapping system with mobile robot.

2. ROOM ACOUSTIC PARAMETERS MAPPING SYSTEM

2.1 Structure of the system

Figure 1 describes a structure of the acoustic parameters mapping system. This measurement system is constructed from two parts: a measurement robot (shown as Figure 2) and an operation unit.

The measurement robot based on i-Cart mini mounts a condenser microphone (AT2020USB+) and a RGB-Depth camera (kinect for windows v1). A mobile robot enables to move sound receiving point. i-Cart mini is a mobile robot platform which has differential-drive wheels for efficient mobility.

The operation unit has three functions: to send trigger that starts measurement, remote control of

[1] s1126017jn@s.chibakoudai.jp

the measurement robot and record sounds.

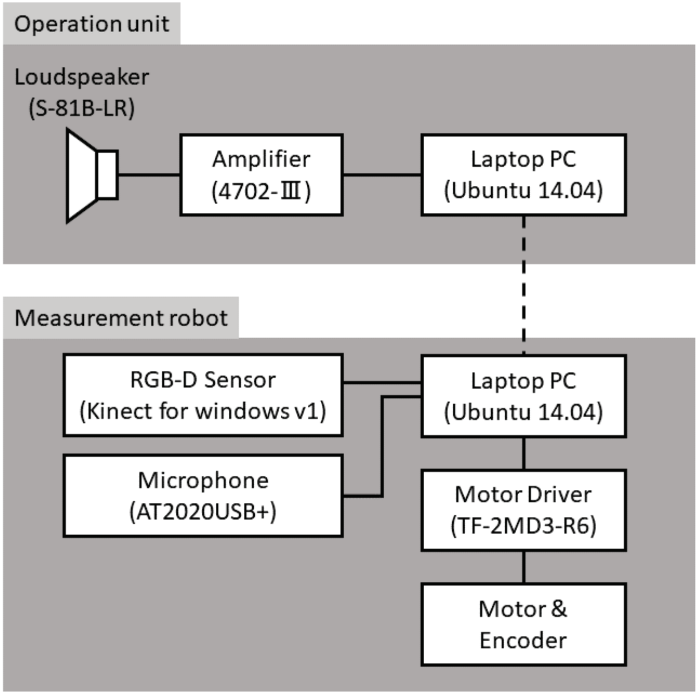

Figure 1 – System diagram of room acoustic parameters mapping system.

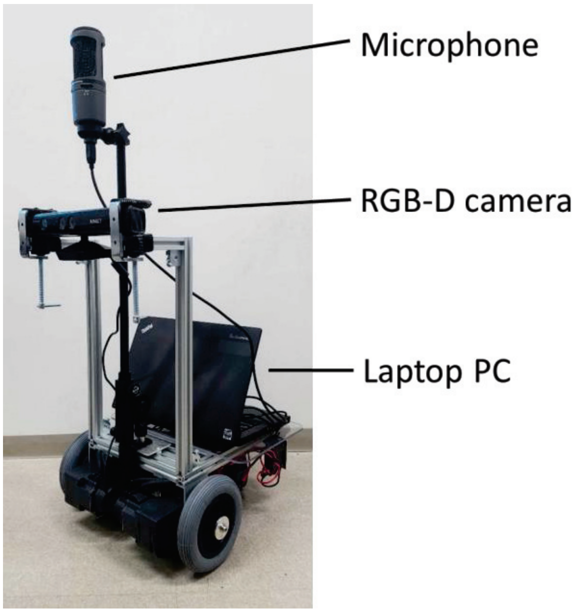

Figure 2 – Overview of the measurement robot.

2.2 IR measurement

Proposed system plays and records a Log-SS signal for IR measurement. The frequency of Log-SS is swept logarithmically. Figure 3 draws a waveform of the measurement signal.

A measurement signal emitted from loudspeaker is consist from 5 cycles of Log-SS. Synchronous addition of the middle 3 cycles of the 5-cycle signal increase the signal-to-noise ratio of the measured signal. Moreover convoluting Inverse Log-SS signal and the synchronous added signal obtains IR.

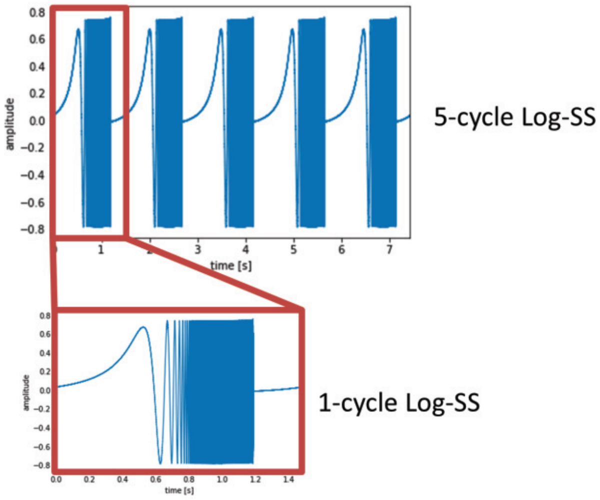

Figure 3 – waveform of measurement signal Log-SS

2.3 Room acoustic parameters

Plotted information on the acoustic parameters distribution map are C_{50} [dB] and early decay time (EDT) [sec]. Each parameter is calculated from measured IRs filtered with 1 octave band; the center frequency is 500 [Hz]. A C_{50} is given by

$$C_{50} = 10\log_{10}\left(\int_0^{50} p^2(t)\,dt \Big/ \int_{50}^{\infty} p^2\,(t)dt\right) \tag{1}$$

, where $p(t)$ is an instantaneous sound pressure at time t [ms]. In addition, an EDT is derived from decay curve $\langle S^2(t)\rangle$ shown follows

$$\langle S^2(t)\rangle = \int_0^{\infty} h^2(t)dt - \int_0^{t} h^2(t)dt \tag{2}$$

, where $h(t)$ is IR. The EDT is determined by multiplying the time taken for 10 dB attenuation on the decay curve by six. These acoustic parameters are known effect to conversation in living rooms (4).

2.4 SLAM

SLAM (simultaneous localization and mapping) of the measurement robot is powered by RTAB-Map (5) that can output a map as 3D point cloud data. SLAM which is widely used for navigation tasks provides information where robot is and a map of the surrounding environment. Proposed system utilizes the self-localization result to record measurement point and draw acoustic information on the mapping result.

Proposed mapping system draw circles filled a color converted from room acoustic parameters on the map generated by SLAM.

3. MEASUREMENT EXPERIMENT

3.1 Condition of experiment

Figure 4 – The experiment environment and the measurement robot.

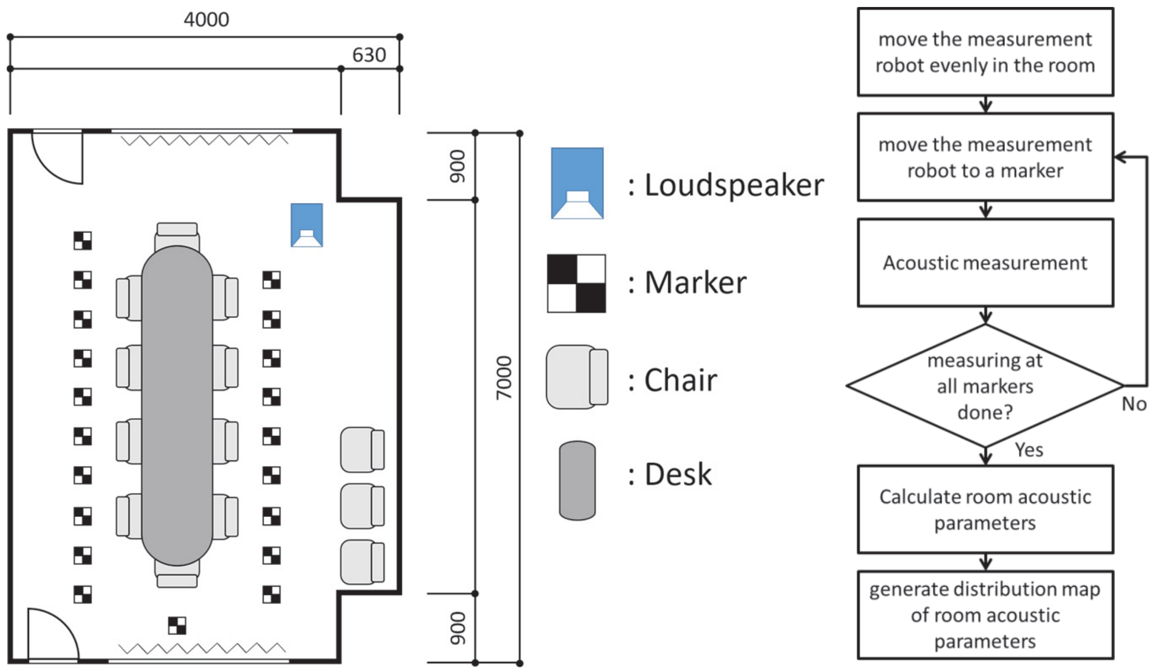

Figure 5 – The condition of experiment environment.

(left: the room layout, right: flowchart of the experiment)

Measurement experiment was performed at a meeting room shown as Figure 4, 5 (left) in Chiba Institute of Technology. The 20 markers indicate points where the measurement robot moves to for examination of position detection accuracy.

Figure 5 (right) shows a flow of measurement experiment. In these processes, we moved the measuring robot by remote control. At first, it is necessary to obtain approximate room shape for accurate self-localization and mapping. Once before acoustic measurement, we moved the measurement robot evenly in the room to generate a map. Note that all steps shown as Figure 4 (right) took about 20 minutes.

3.2 Accuracy of localization detection

The markers shown in Figure 5 (left) indicate a point where the measurement robot moves to for examination of position detection accuracy. Figure 5 shows measurement steps and errors of detected position intervals and marker intervals. From figure 6, position detection accuracy is enough for visualization because errors are less than 210[mm]; this value is narrower than the width of a typical chair.

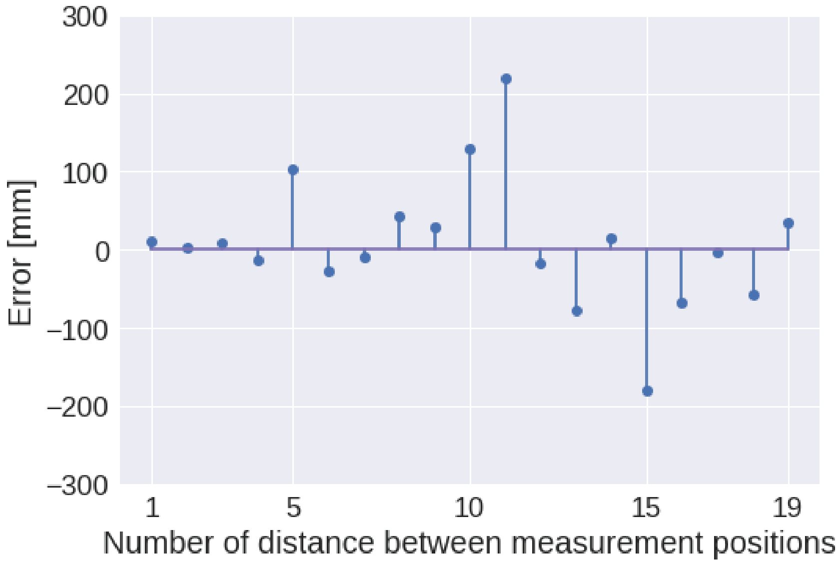

Figure 6 – errors of position detection by measurement steps.

3.3 Acoustic parameters mapping

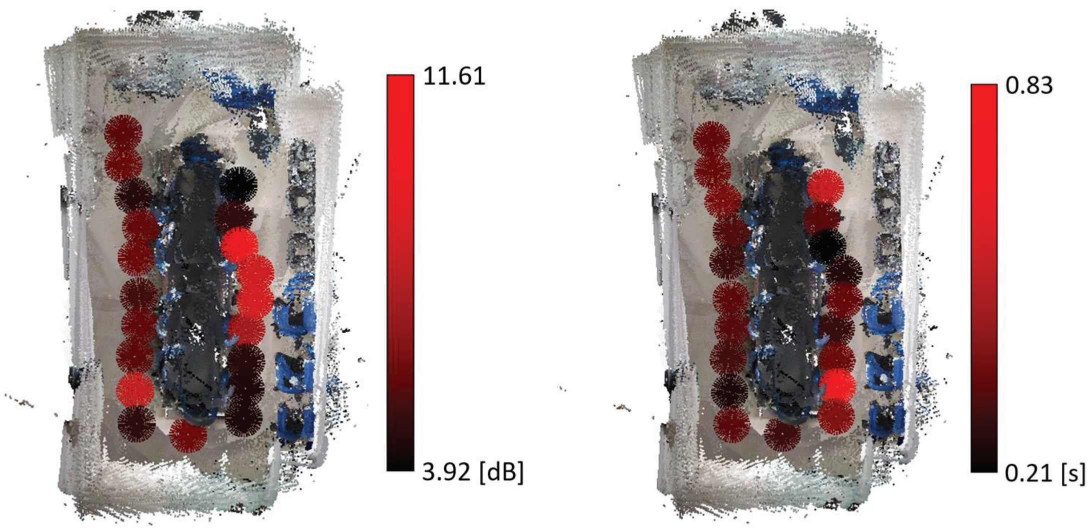

Figure 7 – visualization result as room acoustic parameters maps. (left: C_{50}, right: EDT)

Figure 7 shows distribution maps of room acoustic parameters. The results obtained are reasonable as they are consistent with the general finding that the longer the EDT, the lower the C_{50}. It was found that there are relatively large differences in acoustic parameters even at adjacent seats.

4. DISCUSSION

We showed that it is possible to generate a map about room acoustic parameters by automatic location information acquisition with SLAM. This finding, while preliminary, suggest that adding mobility to acoustic equipment is meaningful for visualization of measurement results.

The distribution of room acoustic parameters drawn on environment map clarified that the hearing differs between the seats. This supports that suggested necessary of location information in previous studies of visualization of sound field.

5. CONCLUSIONS

In this paper, the goal was to assess the efficacy of adding mobility to acoustic equipment for measurement. Thus we proposed using mobile robot to move a sound receiving point and visualized measurement result as a distribution maps.

Further studies of presentation of acoustic information need to be undertaken because we could not discuss validity of 2D distribution expression.

REFERENCES

1. Hisaharu Suzuki, "Visualization of sound field for room acoustical research," The journal of the acoustical society of Japan, vol. 64, No. 7, pp. 399-404, 2008.
2. Yihui Feng, Reza Khodayi-mehr, Yiannis Kantaros, Luke Calkins, Michael M. Zavlanos, "Active Acoustic Impedance Mapping using Mobile Robots", 2018 IEEE Conference on Decision and Control; 17-19, Dec 2018, Miami Beach, USA, pp.3910-3915.
3. Atsushi Watanabe, Jani Even, Luis Yoichi Morales, Carlos T. Ishi, "Robot-assisted Hammer Sounding Inspection of Infrastructures," Journal of the Robotics Society of Japan, vol. 33, No. 7, pp. 68-74, 2015.
4. Hayato Sato, Masayuki Morimoto, Kaori Kobuki, "The effect of reverberation sound on conversation in living rooms," The journal of the acoustical society of Japan, vol. 66, No. 11, pp. 541-551, 2010.
5. IntRoLab, "RTAB-Map Real-Time Appearance-Based Mapping," Retrived June 1, 2019, from (http://introlab.github.io/rtabmap/).