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Acoustical measurements of Japanese Kagura ancient theatres

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ABSTRACT
The Kagura is a specific type of Shinto ritual ceremonial dance and drama offering to the Gods. The Shinto priests act mythological character and play traditional musical instruments on a stage, but the Kagura theatre does not arrange the audience area. I hypothesized that the audience are the Gods enshrined in the main hall and the acoustics is optimized to them. So, I measured impulse responses in the three different types of Kagura theatres and report the acoustical characteristics in the area between the theatre and main hall to identify who is the audience.
Keywords: Kagura ancient theatre, impulse response, absence of audience area, reverberation time

1. INTRODUCTION

The Kagura is a specific type of Shinto ritual ceremonial dance and drama offering to the Gods. Because the Kagura was described first in Kojiki (Japanese history book including myths) edited in the 8th century, the origin may not be later than the century [1]. Today, it is very much a living traditional especially in Shimane and Miyazaki prefectures of Japan, and the Shinto priests act mythological character and play Japanese traditional musical instruments on the stage [2]. To enjoy the performance, we sit on folding chairs lined up around the stage. So that means the Kagura theatre does not arrange the audience area. Who is the audience? I guess that the audience of the Kagura performance is the Gods of the shrine, because the Kagura theatre always locates closely to the main hall in which enshrines God. And I hypothesized that the acoustics of Kagura theatre was optimized to the main hall.

To verify the hypothesis, I measured impulse responses in the Kagura theatres in three shrines (Sata, Kumano and Miho shrines in Shimane) and report the acoustical characteristics in the area between the theatre and main hall to identify who is the audience.

2. ACOUSTICAL MEASUREMENTS

2.1 Kagura Theatres

The acoustical measurements were carried out in three shrines which Kagura theatre have different layouts and structures (Fig. 1). Generally, Japanese shrine is constructed by an entrance gate, worship hall and main hall. The worship hall is a place where we visit to pray, and the main hall is an inner building to enshrine the Gods.

The theatre in Sata shrine is located inside the entrance gate and separated from the worship and main halls (Fig. 1a). The stage is opened in the three sides, and the openings are toward to the main hall. The theatre in Kumano shrine is also separated from the main hall, and the stage is opened in all the four sides. Differently from these shrines, the theatre in Miho shrine is not an independent building, but the stage is included in the worship hall. The worship hall is adjoining to the main hall.

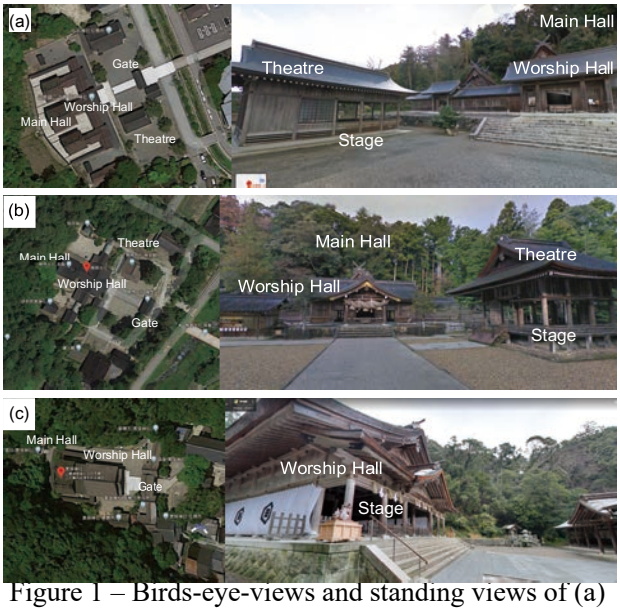

Figure 1 – Birds-eye-views and standing views of (a) Sata, (b) Kumano, and (c) Miho shrines

2.2 Measurement positions

To examine the sound propagation from the theatre and the main hall, Figure 2 shows the measurement positions of impulse responses.

The sound source position was fixed in the area

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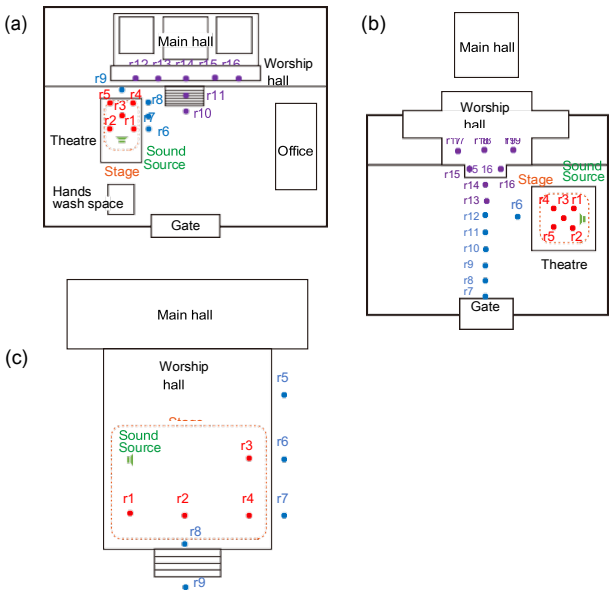

Figure 2 – Displacement of sound source and receiver positions: (a) Sata, (b) Kumano, and (c) Miho shrines

where orchestra members are sitting during the performance. The receiver positions colored in red were on the stage to examine the sound arriving to the performers. The receiver positions colored in blue were around the stage to examine the sound arriving to the human audience. The receiver positions colored in purple were around the main hall and worship hall to examine the sound arriving to the Gods. In preparation for a religion ceremony, the receivers could not be put close to the main hall of the Miho shrines (Fig. 2c).

2.3 Measurement equipment

On the sound source position, a dodecahedral loudspeaker (Type4292, Brüel & Kjær) was put at 1.2 m height from the stage floor. On the receiver positions, an experimenter (body height: 1.65 m) stood wearing a binaural microphone (Type4101, Brüel & Kjær) on his both ears. He always looked toward to the sound source. And a 3D microphone (AMBEO VR MIC, Sennheiser) which outputs sound direction of arrival (DOA) was put next to him at 1.6 m height. The 3D microphone always faced to the gate and turned its back on the worship hall and main hall.

The sound played by the loudspeaker was a swept sine signal from 63 Hz to 16 kHz over 18 s. The left and right data from the binaural microphone and FLU, FRD, BLU, and BRD data (F: front, B: back, L: left, R: right, U: up, and D: down) from the 3D microphone were recorded by a PC (CF-SZ5, Panasonic) via an AD/DA converter (OCTA-CAPTURE, Roland). The sampling rate and size were 44100 Hz and 16-bit. Although the output levels of the signal were varied according to the receivers' positions, the sound pressure levels of the recorded signals were adjusted digitally according to the output levels.

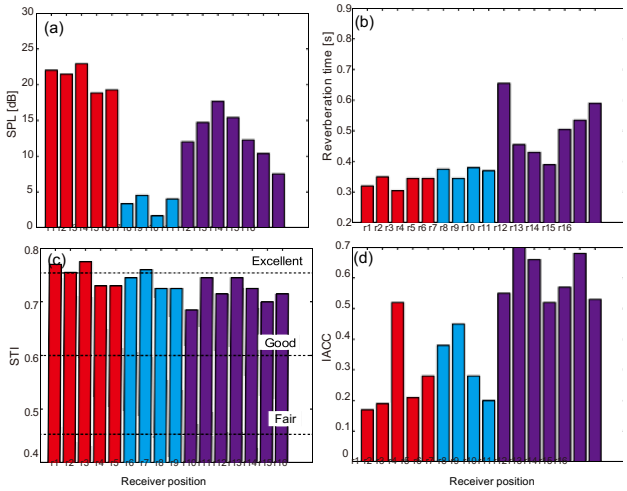

Figure 3 – (a) SPL, (b) reverberation time, (c) STI, and (d) IACC in the Sata shrine. The different colors indicate the receiver pisitions (red bar: on the stage, blue bar: around the stage, and purple bar: around the worship or main hall).

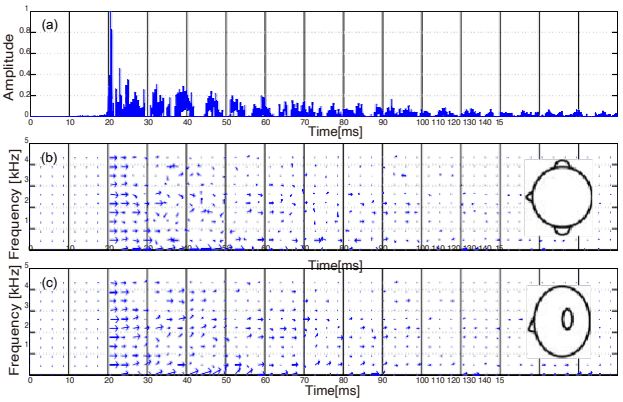

Figure 4 – (a) Relative amplitude, (b) DOA in horizontal plan, and (c) DOA in vertical plan in the receiver position r12 (Sata shrine)

3. RESULTS

From the binaural impulse responses, several acoustical parameters were calculated. And from the 3D impulse responses, the DOA was synthesized. Results shown in this report were limited in sound pressure level (SPL), reverberation time, speech transmission index (STI) [3], and interaural cross-correlation coefficient (IACC) calculated from the binaural impulse responses because of the page limitation.

3.1 Sata shrine

Fig. 3 shows these acoustical parameters obtained in the Sata shrine. The red, blue and purple bars indicate different receiver's zones: on the stage, around the stage, and near the main or worship hall, respectively. From the SPL data, it can be said that the sound on the stage did not arrive to the receiver positions around the stage (blue bars in Fig. 3a). The stage is too high from the ground (1 m), and the audience sitting a folding chair have to gaze up the stage. The stage in the too high position prevented propagating sound around the stage. On the other hand, the sound arrived effectively to the

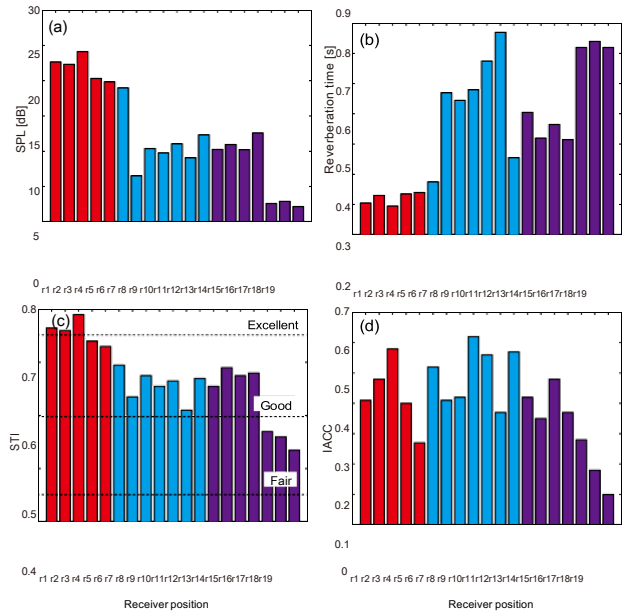

Figure 5 – (a) SPL, (b) reverberation time, (c) STI, and (d) IACC in the Kumano shrine. The different colors indicate the receiver pisitions like Figure 3.

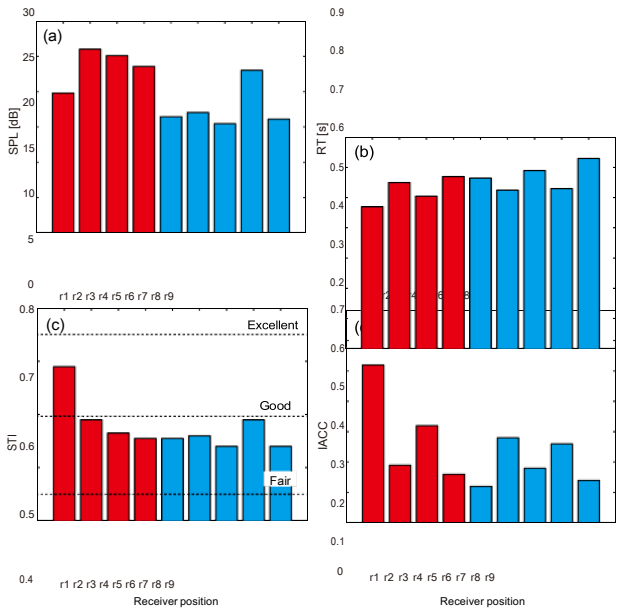

Figure 7 – (a) SPL, (b) reverberation time, (c) STI, and (d) IACC in the Miho shrine. The different colors indicate the receiver pisitions like Figure 3.

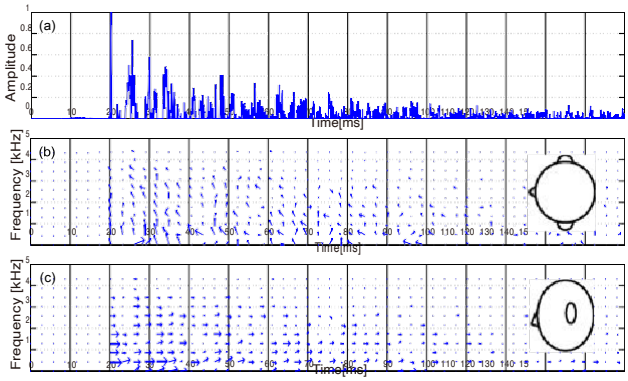

Figure 6 – (a) Relative amplitude, (b) DOA in horizontal plan, and (c) DOA in vertical plan in the receiver position r11 (Kumano shrine)

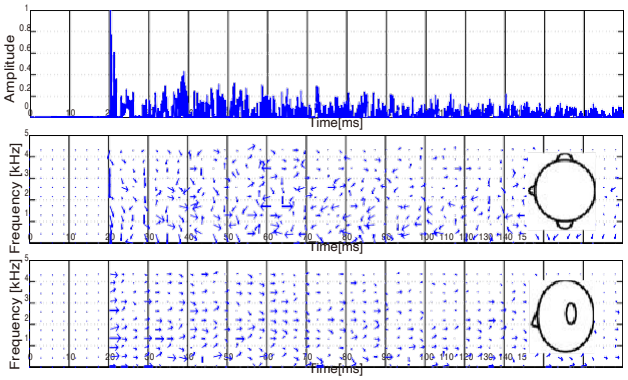

Figure 8 – (a) Relative amplitude, (b) DOA in horizontal plan, and (c) DOA in vertical plan in the receiver position r3 (Miho shrine)

receivers around the worship or main hall (purple bars in Fig. 3a), because the worship and main halls are located upper from the ground 1.57 m, and they are higher than the stage floor. Fig. 4 shows the DOA in receiver position r12 around the worship and main halls. The calculation method of the DOA should be referred to our previous work [4]. The DOA shows that the sound was coming from the bottom (Fig. 4c).

The reverberation times were longer in the receiver positions around the worship and main halls. The reflections from the eaves and walls of the worship hall prolonged the reverberation time. Regardless of the long reverberation times, the STIs were high enough to be rated as good intelligibility. The IACCs around the worship and main halls were higher than the other receiver positions. It means that one can recognize the DOA from the stage clearly.

3.2 Kumano shrine

Fig. 5 shows the acoustical parameters obtained in Kumano shrine. The SPL was decreased as the distance between source and receiver was longer. Because the stage in the Kumano shrine is opened in all the four sides (Fig 1b), the sound propagation behaved in much the same way as a free sound field. We consider that the Kagura theatre in Kumano shrine has varied the purpose from shrine ritual to popular entertainment in the history, and the stage design has been optimized for the human audience. The reverberation times were longer for the receiver positions (r17 – r19 in Fig. 5b) in the worship hall due to the reflections in the hall, and the speech transmission qualities were rated as fair intelligibility (Fig. 5c). The reflections in the worship hall decreased also the IACC (Fig. 5d).

Fig. 6 shows the DOA in the receiver position r11, which is the center of the shrine area, and the reverberation time of this position was the longest as shown in Fig. 5b. The direct sound around 20 ms was arrived from the source position (left side), and the subsequent reflections were arrived from the worship hall (left rear side). Since the halls and gate are scattered in the shrine area, the reflections reach partially.

3.3 Miho shrine

Fig. 7 shows the acoustical parameters obtained in Miho shrine. The sound field in Moho shrine was characterized by the long reverberation time (Fig. 7b). Because the stage for Kagura performance is embedded in the worship hall, the stage area is the largest in the three shrine and the large ceiling covers it. The complex reflections in the stage obscured the speech transmission quality (Fig. 7c) and decreased the IACC (Fig. 7d).

Fig. 8 shows the DOA in the receiver position r3, which is on the stage (Fig. 2c). The direct sound was arrived from the source position (right side), and the subsequent reflections were arrived from the various directions. This diffused sound field prolonged the reverberation time and decreased the IACC.

4. DISCUSSIONS

The three Kagura theatres measured in this study are quite different in terms of the current operations and styles. The Kagura performed in the Sata shrine keeps the dancing style and musical playing based on age-old belief and is registered as UNESCO Intangible Cultural Heritage ("Sada-shinnou,") [5]. It means the Kagura theatre in Sato shrine is the most suitable for calling "ancient theatre." The stage was optimized for viewing for the Gods in the main hall (e.g., openings in three sides toward to the main hall), and the sound was arrived effectively to the main hall, too (Fig. 3). Although the reverberation times were the longest around the worship and main halls, the speech intelligibility was kept in "Good." The reason that the acoustics around the worship and main halls was excellent is the floor level. The floor level (1m) of the stage is too high to enjoy the performance sitting around the theatre; however, the floor level of the stage meets that of the worship and main halls, and then the sound propagates effectively to them.

Although Kumano shrine hosts the Kagura performance offering to Gods, the theatre is used often for the other events (e.g., soybeans scattering ceremony). It means that the role of theatre has been varied for a public space in the history. And the current theatre was relocated from the worship hall in 1978. The stage has the all four-side openings, and the sound propagation from the sound source on the stage was approximately the same manner in a free sound field.

The theatre in Miho shrine is covered by the large ceiling (height: 7m at a maximum), so that the sound in it propagates diffusely unlike the Sata and Kumano shrines. The reverberation time was the longest in the three shrines and is not suitable for the drama performance but the historical musical performance like a concert hall. The Miho shrine has enshrined the Gods of music, and many musical instruments have been devoted. Differently from the other two shrines, Kagura is not performed annually in the theatre, but female attendants dance to the music twice in every day (8:30 and 15:30). Due to the good acoustics, the theatre is used often for the other musical performances (e.g., classic and pop music).

5. CONCLUSIONS

Although I hypothesized that the acoustics of Kagura theatre was optimized to the main hall where the Gods exist, the hypothesis was not demonstrated for all the three theatres measured in this study. The role of Kagura theatre has been varied in response to the need of the times. In the three shrines, the Kagura performance in the Sata shrine preserves the style more closely to the original one, and the acoustics in the Kagura theatre is optimized to propagate sound effectively to the worship and main halls. The Kagura theater might be designed while assuming that the audience is the Gods.

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