Preference of reverberation time for musicians and audience of the Javanese traditional gamelan music

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Abstract - This paper presents results of an investigation of room acoustic parameters those are appropriated particularly to perform a Javanese gamelan. The acoustic parameters were obtained by analysing simulated sounds of performance. Those simulated sounds were obtained by sound convolution technique of a dry sound signal of Javanese gamelan performance with impulse responses rooms whose appropriated reverberation time. The reverberation time were varied between 1.0s to 1.8s, those belong to the characteristic of Pendopo Mangkunegaran Surakarta. In this case, Pendopo Mangkunegaran is assumed as one of the most suitable concert halls for Javanese gamelan performance.

To obtain the acoustic parameters, we used a psycho-acoustics measurement based on paired comparison test that having different of acoustic parameters to determine the most comfortable one to majority of respondents. The respondents who have participated in this research composed of a group of professional musicians of Javanese gamelan and groups of audience who are not musician, nevertheless part of them were familiar with Javanese gamelan music.

The comparison test gave results and showed majority of respondents of group of musicians had a notion sound reverberation time of 1.2s was most comfortable. This corresponds to +6.2dB, clarity and 74% definition. It means the appropriate acoustic condition allows musicians to recognize and distinguish clearly sound of each instrument being played. Meanwhile, group of audience had a notion reverberation time in a range of 1.2s – 1.6s was most comfortable. This range of reverberation time corresponds to +4dB to +6.2dB of clarity, and 66% to 74% of definition.

1. Introduction
The Javanese traditional gamelan is a kind of ensemble of instruments of gamelan called ricikan. There are two groups of Javanese gamelan called pelog and slendro, each has 40-70 types of ricikan. Alike a classical orchestra, Javanese gamelan is played by a group of musicians, each musician play a type of ricikan. It is very common a performance of the Javanese traditional gamelan is accompanied by vocalist called sinden. The existence of sinden during a performance is not separated of the Javanese traditional gamelan. During the performance, along with the rhythm of the gamelan music, sinden singing a Javanese song, in form of a Javanese poetry, containing a message to audience. The existence of sinden together with the gamelan as an ensemble makes a performance of the Javanese traditional gamelan more interesting and traditionally invites much public audience. However, as a kind of music ensemble, there is no a leader who leads the Javanese traditional gamelan.
Since there is no a leader who leads the performance, harmony of performance of the Javanese traditional gamelan then is absolutely depends on ability of each musician (call pengrawit) and vocal to recognize and distinguish sound of each instrument of gamelan being played during the performance. Recognizing and distinguishing sound characters is a necessary for musicians to determine tempo, next tones and loudness of each instrument during the show. Therefore, musicians of the Javanese traditional gamelan need a specific acoustic preference in order to be able to take their role in a performance [1,2]. For the same reason, to enjoy a performance of the Javanese traditional gamelan, audience require its own acoustic preference which is different to musicians preferred. Audience need impression of space in addition to the acoustic parameters of the gamelan.

Reverberation time (RT) is an important acoustic parameter that affects to ability of musicians to play their role. The longer reverberation time results less sound clarity in a room [3,4]. In return, musicians would get difficulty to play ricikan appropriate to their role in a performance. Using the principle impulse response at a position in space can be determined acoustic parameters associate to that position including of reverberation time, subsequent reverberation time, sound clarity, frequency contents, and loudness [5].

Early in the past, the Javanese traditional gamelan actually was part of traditional and religious ceremony held usually in Kraton. Kraton is the Palace of the Javanese Kingdom in ancient times. Along the performance, sinden sing a song enjoy a cultural message to audience. Therefore the performance event invites people to come for the message of goodness. For that reason, in the past, the Javanese traditional gamelan was performed traditionally in an open space or semi-open space in order to accommodate more audience. In the progress, function of performance of the Javanese traditional gamelan has changed gradually becomes a kind of public entertainment. However, in present time, noises that come from environment make open space or semi-open space becomes not very ideal place to conduct the performance. In consequence, performances of the Javanese traditional gamelan move from open or semi-open space to enclosed space, therefore straight changes room acoustics of the performance is unavoidable. To solve the acoustic problem it is very common one installs an electronic system like loudspeaker, which is actually doesn’t help but getting worse. The direct affects results clarity of sound in the room is decreasing, then, therefore the musician’s loss their precision in the way of playing gamelan. In turn, gradually change of the performance character of the Javanese traditional gamelan has been occurred. Moreover, following the advancement of technology and lifestyle, the presence of the Javanese traditional gamelan in enclosed space whose no appropriated acoustic characteristics finally has shifted number of meanings the authenticity of performances from its originally when it was performed at an open or semi-open space. In order to get the originality of performance, it's necessary to find a design preference of acoustic parameters appropriated to an enclosed space particularly for the Javanese traditional gamelan. That is, an enclosed space which has acoustic parameters equivalently found in a semi-open space where the Javanese traditional gamelan originally was performed. In this case, the acoustic parameters of design must provide acoustic environment desired by musicians and audience as likely it was obtained when the performance was conducted in semi-open space.

Among parameters of a room acoustics, reverberation time is the most important, especially on stage area where musicians are playing gamelan. Long of reverberation time on stage area will influence sound clarity perceived by musicians and vocalist and its can disturb performance harmony and performance communication among the musicians. In addition, the reverberation time of room will present a temporal impression and character of the Javanese traditional gamelan during a performance. For that reason, a study of preference of reverberation time, to find one the most preferred for musicians and audience in an enclosed space, is really important to design a room acoustics for the Javanese traditional gamelan.
Assessments of a quality of performance of the Javanese traditional gamelan usually are based on subjective factors. The results will depend on background and attitude knowledge of who becomes a judge. Because of the attitude of respondents are varying, the results of a subjective assessment are difficult to be realized as standard of acoustic design parameters. In return, because of no standard preference which is appropriated to the acoustic characteristic of the Javanese gamelan makes quality of the performance are inconsistent depends on enclosed room where the performance is. As mentioned previously, it is very often an acoustic modification is made by using a sound system or loudspeaker to adjust sound acoustic parameters of the enclosed room where the performance is conducting. However, loudspeaker may exacerbate other acoustic parameters and even overall of the performance. Therefore, finding objective parameters of the acoustics performance is necessary to have a standard design of enclosed room particularly for Javanese traditional gamelan.

The equivalent objective parameters from the obtained subjective assessment are called as quantified subjective parameters [6]. By quantification of the subjective parameters in order to get the equivalent objective one, the standard of design can be obtained and to be used in designing an enclosed room appropriately for the Javanese traditional gamelan. And then, hypothetically musicians will re-find their ability to keep the quality and authenticity of performances.

It is well known that the Pendopo Mangkunegaran at Surakarta is much closed to history of progress for years of the Javanese traditional gamelan. It is a semi-open space where the Javanese traditional gamelan was played and performed for generations. Therefore, it is a basic reason that acoustic parameters of the Pendopo Mangkunegaran then is referred as standard preference to derive equivalent or appropriate acoustic parameters for enclosed space for the Javanese traditional gamelan performance. Suyatno [7] has reported the room acoustic characteristics of the Pendopo Mangkunegaran at Surakarta. Those parameters are distribution of listening level, reverberation time, clarity (C80), definition (D50) and Inter Aural Cross Correlation (IACC). By referring to the acoustic criteria given by Ribeiro [8], the Pendopo Mangkunegaran actually has acoustics parameters which are appropriately equivalent to prerequisites as a performance venue [8].

Sarwono on his research of an optimum reverberation time appropriate to audience who are unfamiliar to Javanese traditional gamelan is in the range of 500 ms - 650 ms [9]. Those ranges of reverberation time were obtained by psycho-acoustic test using a sound field of performance of the Javanese traditional gamelan that was recorded by mixing, filtering and an artificial effect. While Fariz et al [10] by using the scoring method found the acoustic parameters preference for the Javanese gamelan are 1.4 s of reverberation time, 69 dB - 79 dB of listening level, and 40 ms of initial time delay gap.

In this research, the psycho-acoustic test was conducted to sounds of performance of the Javanese traditional gamelan using a pairwise comparison test method [11]. In this test, each respondent is ordered to listen by using a headset a pair of two sounds which have different acoustic parameters. Then the respondent should select the considered most pleasant one. Using such test method has been obtained acoustic preferable parameters which were chosen by majority of the respondents. Where, hypothetically those acoustic parameters are appropriate to perform the Javanese traditional gamelan.

In section II of this paper will be explained more detail methodology of this research, including creation of the simulated sounds, and method of comparative test used in this research. While in section III will be described results of the comparative test, those are most appropriate acoustic parameters to the musician and audience of the Javanese traditional gamelan. And the conclusion will be given in last section of this paper.
2. Numerical Methods
As stated in previous section, subjective assessment of acoustics quality of performance of the Javanese traditional gamelan depends relatively very much on background and the momentally attitude of the "assessors" or respondent, who being a judge. Actually, musicians and audience of the Javanese traditional gamelan have different preference in term of acoustic parameters to enjoy a performance. To conduct their role to a performance, musicians require their own acoustics preference. As has been mentioned previously noted, an important acoustic parameter that influences to acoustics quality is reverberation time. To find the reverberation time which is most pleasant to musicians and audience, it was conducted by a psycho-acoustic test upon appropriated simulated sounds. In this research, simulated sounds were obtained by convolution process of a dry sound signal to impulse response of rooms of differences of reverberation time [12]. Variations of parameters of reverberation time are 1.0 s, 1.2 s, 1.4 s, 1.6 s, and 1.8 s. Those parameters are acoustic parameters of Pendopo Mangkunegaran. Table 1 describes acoustic parameters of impulse responds used in the convolution technique (equation 1).

Table 1. Acoustic parameters of responses impulse for synthetic rooms.

| Parameters | Room’s Parameters |
|------------|-------------------|
| RT [second] | 1.0 1.2 1.4 1.6 1.8 |
| Clarity (C80) [dB] | 8.7 6.7 5.2 4.0 1.2 |
| Definition (D50) [%] | 82.1 75.4 68.5 66.3 44.8 |

A convolution technique that was used to create the simulated sound used in this research is represented by the following equation:

\[ y_i(t) = \int_{-\infty}^{\infty} x(\tau) h_i(t - \tau) d\tau \]  

(1)

In equation (1), \( x(t) \) is dry sound signal, \( h_i(t) \) is “synthetic room” impulse response represents “synthetic” acoustic parameters of \( i^{th} \) room, while \( y_i(t) \) represents a simulated sound that was assumed was conducting in \( i^{th} \) room. By using this concept, a simulated sound of performance of the Javanese traditional gamelan can be obtained having the desired acoustic parameters. In this case, the rooms have acoustic parameters belong to Pendopo Mangkunegaran.

Have been stated previously, an objective of this research is to obtain equivalent objective parameters from a subjective assessment. In order to obtain a suitable criterion by musicians and audience, the types of respondents as assessors are the players and audiences. In this research respondents compose of 39 musicians and 94 audiences who were non-musicians or audience. The musicians were professional and expert in playing the Javanese gamelan instruments. The musician respondents came from the laboratory technicians at ISI Surakarta and other professional gamelan artists. Table 2 describes qualification and background of the respondents.

Table 2. Qualification and background of respondents participated in comparison test.

| Type of Respondents | Background |
|---------------------|------------|
| Musicians:          | 30 respondents are expert of the Javanese traditional gamelan |
| 39 respondents      | 9 respondents are expert and can play all the Javanese gamelan instruments |
| Audience:           | 61 respondents are familiar with the Javanese traditional gamelan |
| 94 respondents      | (audience type A): |
|                     | 37 respondents play the Javanese traditional gamelan |
|                     | 24 respondents don’t play the Javanese traditional gamelan |
|                     | 33 respondents are unfamiliar with the Javanese traditional gamelan |
|                     | (audience type B) |
To obtain the equivalent objective parameters, it was used Thurstone scaling method. In what follows will be explained steps of quantification in order to obtain the objective parameters from subjective assessment. By Thurstone scaling method, each the respondent was ordered to hear a pair of any two sounds. Each respondent has a freedom to choose the most pleasant sound one. In this paper, the type of composition (called garap) that was tested by respondents has a moderate-to-fast tempo which called soran. During subjective assessment, \(i^{th}\) simulated sound will be compared by \(j^{th}\) simulated sound, and \(k^{th}\) respondent will select which one of the two simulated sounds is preferred. Figure 1 shows example of two simulated sounds of performances of Javanese traditional gamelan should be selected by respondent.

![Figure 1. The simulated sounds for pairwise comparison test.](image)

There are 5 simulated sounds represented by Table 1, each represent reverberation time of 1.0s, 1.2s, 1.4s, 1.6s and 1.8s respectively. After heard \(i^{th}\) and \(j^{th}\) simulated sounds subsequently, respondent should determine only one which is preferred. When \(i^{th}\) simulated sound is preferred then the numerical preference scale is given by \(Y_{ij}(k) = 1\) and \(Y_{ji}(k) = 0\). Otherwise when \(j^{th}\) simulated sound is more preferred one, then the numerical preference scale is \(Y_{ij}(k) = 0\) and \(Y_{ji}(k) = 1\). By this comparative test method numerical value of scale is defined to be \(Y_{ij}(k) = 0.5\) when \(i=j\). There are 10 pairs of two simulated sounds to be assessed. Then, preference distribution \((S(k))\) is calculated using the following equation [11]:

\[
S_{i(k)}(1) = \sqrt{2\pi}(P_{i(k)} - 0.5) \quad i = 1,...,5
\]

where \(P_{i(k)}\) is

\[
P_{i(k)} = \frac{1}{M} \sum_{j=1}^{M} Y_{ij}(k) \quad i, j = 1,...,5
\]

And \(M\) is number of simulated sounds to be tested, in this experiment, is equal to 5. It is clear every respondent have 10 pairs of two simulated sounds to be assessed to obtained \(S(k), i=1,...,5\). To avoid a bias that occurs in psychoacoustic tests, pairs of two simulated sounds to be assessed by a respondent was ordered randomly. Table 2 shows an example of results of the psychoacoustics test. According to Table 3, the highest of \(S(k)\) is equivalent to reverberation time of 1.4 s.

| \(i\) | \(RT[s]\) | 1   | 1.2 | 1.4 | 1.6 | 1.8 | \(S_{i(k)}\) |
|------|----------|-----|-----|-----|-----|-----|------------|
| 1    | 0.5      | 0   | 0   | 0   | 0   | 1   | -0.501     |
| 1.2  | 1        | 0.5 | 0   | 1   | 1   | 1   | 0.501      |
| 1.4  | 1        | 1   | 0.5 | 1   | 1   | 1   | 1.002      |
| 1.6  | 1        | 0   | 0   | 0.5 | 1   | 0   | 0.000      |
| 1.8  | 0        | 0   | 0   | 0   | 0.5 | -1.002 |          |

Finally, numerical value of appropriate objective parameter of acoustic preference that which is equivalent to the subjective assessment is obtained by averaging of results given by all respondents:

\[
S = \frac{1}{N} \sum_{i=1}^{N} S_{i(k)}
\]

The \(k\) index in equations (1)-(3) represents respondent was participated, while \(N\) in equation (4) is number of respondents were participated, which is 39 musicians and 94 audience (type A and type B all together).
3. Results and Discussion

3.1. Appropriate Acoustic Parameters for Musicians

Using procedure as explained previously, Figure 2 shows distribution plot of numerical values of reverberation time preferred by respondents of musician.

As shown by Figure 2, acoustic reverberation time which was most preferred by musicians is 1.2s. Referring Table 1, 1.2 s reverberation time gives good sound clarity as shown by values of C80 is 6.7 dB and D50 is 75.4%. Those values, hypothetically indicate that majority of musicians have an ability to recognize and distinguish the instruments were playing and vocals as well. Such acoustic condition guaranty a good performance communication among musicians and harmony of performance can be obtained.

3.2. Appropriate Acoustics Parameters for Audience

Using the same procedure, assessment by audience respondents (audience of type A and audience type B) have been resulted distribution of acoustic reverberation time shown by Figure 3.

A Figure 3 show the highest preference comes from audience of type A is 0.36 which is 1.2 s of reverberation time. Again, referring to Table 1, the equivalent room has acoustic characteristics C80 of +6.7 dB and D50 of 75.4%. While the highest preference comes from audience type B is 0.24 which is 1.6 s of reverberation time. Where, according to Table 1, the equivalent room has acoustic characteristics C80 of +4 dB and D50 of 66%. By those results, in can be concluded the audience feel comfort for the room with reverberation time of 1.4 s and 1.6 s. This may occur because of background of the respondents were familiar and could play the gamelan even they are not expert on it, therefore they require impression of space as well [1]. As noted by Table 2, among audience type A, 55 % are beginner musicians that do Javanese traditional gamelan and the rest are doesn’t but just enjoy.

3.3. Discussion

The acoustic parameters that suitable to musicians and audience of the Javanese traditional gamelan allow each of them to enjoy and carry out their respective roles in a performance. Refer to Figure 2,
not only was the clarity of sound required by musicians, but also the reverberation of the room still needed. It can be seen from the most respondents’ musicians more pleasant with the sound produced by room with RT values of 1.2 s than 1.0 s. The reverberation of room is still needed to emerge the strong impression (called gagah) of the Javanese gamelan performances [1,13]. Table 4 shows the acoustics parameter preferred by majority of respondents of musicians and audience obtained by comparison test explained previously.

Table 4. Acoustic parameters preferred by musicians and audience of the Javanese traditional gamelan

| Parameters | Musicians | Audience |
|------------|-----------|----------|
| RT         | 1.2 s     | 1.2 s – 1.6 s |
| C80        | 6.7 dB    | 4.0 dB – 8 dB |
| D50        | 75.4 %    | 66 % - 82 % |
| BR         | 0.92      | 0.96 – 1.04 |
| TR         | 0.99      | 0.7 – 0.92 |

According to Table 4, like a classical music, sounds were produced during a performance of the Javanese traditional gamelan chosen by majority of musicians have temporal impressions of warmth (BR=0.92) and brilliance (TR=0.99). Warmth is the subjective impression of the sound at the low frequency (125 Hz and 250 Hz) and the brilliance is high frequency (2000 Hz and 4000 Hz) [3,4]. Like musicians, as shown by Table 3, sounds were chosen by audience have good impression. To be noted, numerical value of TR less than 1 (TR=0.7) is accepted as a brilliant impression, since all instruments (ricikan) produce sounds with frequency less than 4000 Hz. Yet, in most of performances, sounds produced by instruments have dominant frequencies less than 3000 Hz [14, 15].

Based on the parameters in Table 4, the player can still identify instrument and vocal, but still have a strong impression. Therefore, in order to maintain communication among the musicians and harmony of performance during the show, acoustics design and material selection for stage must be able to reduce low-frequency and long sound envelope characteristic.

As for the audience, temporal impression obtained through the reverberation time to make the space more real presence, but with clarity of voice and instrument can still be obtained. While, in audience area for Javanese gamelan performance, model of room and ceiling are expected to provide a reflection that is not excessive.

Thus, elements of direct sounds and sounds of reflection in a closed room must be maintained such that to produce reverberation time properly needed by musicians and audience as well. Finally, by the acoustic parameters shown by Table 3, the meaning and originality of performance of the Javanese traditional gamelan conducted in an enclosed space can be obtained as such likely a performance was traditionally conducted in semi-open or open space.

4. Conclusions

To get a performance harmony and performance communication among musicians of the Javanese traditional gamelan, the musicians need acoustic clarity of each instrument of the gamelan during the performance. Sound clarity is influenced by reverberation time of room. In this research has been shown majority of respondents of musicians selected RT of 1.2 s which is equivalent to D50 of 74%, as well as C80 of +6.2 dB. By those acoustic parameters it is guaranteed musicians got an acoustic clarity needed to play well their role. It means musicians can recognize and distinguish well ricikan are being played. In return, at a time, each musician knows very well which instrument should be played according to their role of the show. On the other hand, majority of respondents of audience selected reverberation time between 1.2 s - 1.6 s, that is equivalent to C80 between +4 to 6.2 and D50 are 66% - 74%. Through those parameters, the audience can enjoy performances with good acoustic qualities include the impression of room by the RT.
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