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Subjective Preference of Reverberation Time in Various Listening Level for Gamelan Degung Sunda Using Psychoacoustic Test

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Abstract:

Acoustic performance of concert hall depends on four parameters. Each parameter has specific optimum value based on musical instrument characteristics. However, optimum value of monoaural parameters for Gamelan Degung Sunda have not examined yet hence there is no reference of acoustic value to build a concert hall. Subjective preference of subsequent reverberation time in various listening level is determined by using psychoacoustic test. There are numbers of respondents from various background & knowledge about Gamelan Degung were involved. They were asked to ranked different sound samples. Evaluation of statistical analysis using ANOVA shows that background & knowledge of respondents has strong relation to respondents' ability to distinguish sound samples. The optimum value of subsequent reverberation time is 1 s for all listening level value. Moreover, 1.8 s may be considered as optimum value whenever listening level value is 74 dB.

INTRODUCTION

Gamelan Degung Sunda is a tradition music from West Java province of Indonesia. It contains set of instruments music (waditra) such as baron, goong, rebab, saron and so on. During the show, all waditras is played as an ensemble just like an orchestra.

Each waditra has specific character both spatial, temporal and spatial [1,2]. Character of Sundanese' musical instruments are different to musical instruments originated from Central Java [3]. Moreover, aerophone instrument and bowed-string instrument from China has different characteristics to Gamelan Degung Sunda [4-5]. Moreover, the purpose of acoustic design has to be clear whether it is dedicated for performers or audience since both requires different acoustic condition [6].

There are 4 important parameters in assessed a concert hall: Listening Level (LL), Sub-sequence reverberation time (T_{sub}), Initial Time Delay Gap (Δt_1) and Inter-Aural Cross Correlation (IACC) [7]. Each parameter has different preferred value depend on sound sources characteristic being performed. For example, a lecture and conference room has to be designed with signal around 0.5 s of T_{sub}, while an orchestra for vocal music requires 0.5-1.0 s [8]. Differently, recommendation value of T_{sub} for orchestra music is around 1.0-1.8s [7]. Also, the optimum value of T_{sub} for Balinese Gamelan and Javanese Gamelan is different too [9-10]. The other parameter has preferred value of Δt_1 and IACC for Javanese is around 24-25 ms with lower IACC [10]. The Chinese national instruments are believed has optimum value of IACC between 0.20-0.41 [11].

Only two monoaural-temporal parameters are discussed in this research: Listening level and Subsequence Reverberation time. Both temporal factors are obtained from autocorrelation function (ACF). Previous researches have shown that electric guitar and type of guitar strokes is strongly related with psychoacoustic [10-11]. The object of this research is to find the optimum value of T_{sub} with vary of LL. The test involved numbers of respondents from various background and knowledge about research object since the initial hypothesis was it has relation with the ability to distinguish the samples.

ACOUSTIC PARAMETERS

The optimum of acoustic design objectives can be described as arriving signal at ears which represent in spatial and temporal factors. Both factors are important criteria to achieving optimum acoustics design. In this research, only temporal-monoaural parameters are discussed.

The energy intensity of sound signal that emitted from sources may be represented as pressure function p(t) in time domain. The mathematical expression of it as follows

$$p(t) = \int_{-\infty}^{\infty} P(\omega) e^{j\omega t} d\omega \quad \ldots\ldots(1)$$

Whenever there might be a delay time (τ) between emitted and arrival signal hence the autocorrelation function (ACF) during period of interval time T between those signal is defined by

$$\Phi(\tau) = \lim_{T\to\infty} \frac{1}{2T} \int_{-T}^{T} p(t)p(t+\tau)dt \quad \ldots\ldots(2)$$

The ACF may be normalized as

$$\phi(\tau) = \frac{\Phi(\tau)}{\Phi(0)} \quad \ldots\ldots(3)$$

The normalized of ACF reaches maximum point at τ=0. Physical meaning of ACF=1 is both signal is similar. Whenever $\phi(\tau) = 0.1$, the delay time τ, named as τ_e, defined as effective duration of ACF. The delay time τ_e is used to calculate the preferences. Approximate value of T_{sub} optimum for orchestra can be calculated through following equation

$$T_{sub} = 23 * \tau_e \quad \ldots\ldots(4)$$

The equation (4) is not applicable for all sound sources. All different type of sound sources has different recommendation of T_{sub} as illustrated by Figure 1.

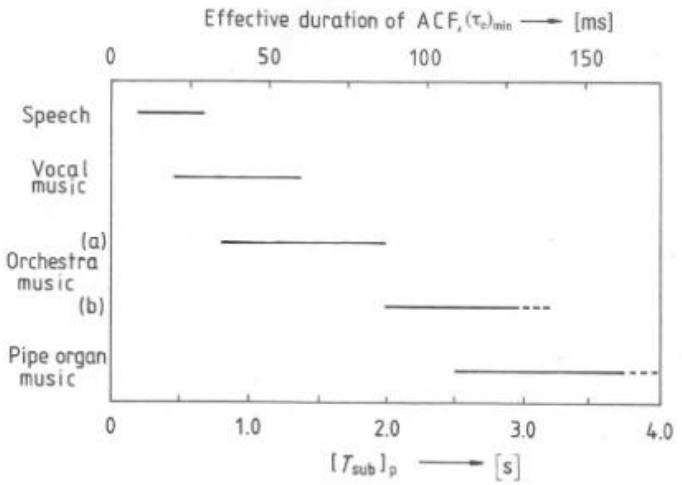

Figure 1. Recommendation value of T_{sub} [6].

ACF also relates with another temporal factor, listening level (LL). The preferred value of LL depends on music motif (Ando, 2007). In this experiment, LL was set to monoaural parameter with delay time τ=0 hence it is expressed by

$$LL = 10\log\frac{\Phi(0)}{\Phi(0)_{ref}} \quad \text{.....(4)}$$

where $\Phi(0)_{ref}$ is ACF reference. Similar with T_{sub}, recommendation value of LL depends on music or instruments being played.

METHODOLOGY

The research contains several steps need to be done in order. Brief description of each step is explained as follow

Sample Preparation

The purpose of this step is to get sound samples with vary acoustic parameters. Samples were made from acoustic modification of raw data. It was taken from live recording of Gamelan Degung Sunda performance. The desired physical condition is rich in direct sound and less or no reverb sound. Based on consideration, the recording process was taken at musical studio.

Next, raw data has to be modified so it has certain acoustic properties. Since only T_{sub} and LL are considered as factors therefore two others parameter are intentionally kept as constant. The variation value of T_{sub} and LL was carefully designed. The different between the smallest value has to be larger than just noticeable different (JND).

The sound sample production is to convolve raw data with room impulse response (RIR). It is synthesized through auralization method by using specific software. Mathematical expression to produce sound sample is

$$\mathbf{y(t)_i = p(t) * RIR(t)_i} \quad \text{.....(5)}$$

where y(t) is output function, RIR is Room impulse response and i is for number of sample(s). RIR was set to produced to obtained samples with 1 s, 1.4 s, 1.8 s, 2.6 s and 2.8 s of T_{sub} and 70 dB, 74 dB, 78 dB and 82 dB of LL.

Psychoacoustic Test

Optimum value of either T_{sub} and LL is examined through psychoacoustic test. It involves numbers of respondents from various background and knowledge about Gamelan Degung Sunda. It is classified into three group: (A) for respondents with no or less experience to Gamelan Degung Sunda, (B) for enthusiast respondents and (C) for expert respondents / musicians in Gamelan Degung Sunda. Number of respondents was 11 persons for each group.

All respondents were asked to rank samples based on 'most favour' and 'disfavour' of each samples by put number between 1-5. Number 1 is for least favour sample and 5 is for the most favour sample. Respondents were allowed to hear samples in limitless repetition before they made a decision.

After surveys, data was analyzed statistically using one-way ANOVA with P-value 0.05 to examined whether samples are perceived differently. Further test was required whenever those samples have different mean statistically. The test was Least Significant Different (LSD) with objective to categorized similar perceived samples.

RESULTS and DISCUSSION

To determine the optimum value of T_{sub}, it can be chosen from particular group based on respondents' ability to distinguish different samples. It is examined by statistical analysis of ANOVA. The summary of it is shown at Table 1. According to it, all respondents from all group has sufficient ability to differentiate the samples.

Table 1. Summary of ANOVA analysis

Samples	Group		
	A	B	C
Various T_{sub} at 66 dB	Significantly different	Significantly different	Significantly different
Various T_{sub} at 70 dB	Significantly different	Significantly different	Significantly different
Various T_{sub} at 74 dB	Significantly different	Significantly different	Significantly different
Various T_{sub} at 78 dB	Significantly different	Significantly different	Significantly different
Various T_{sub} at 82 dB	Significantly different	Significantly different	Significantly different

Therefore, it requires further analysis to find group which group has the best ability. It can be fulfilled by conduct LSD test to all group. It tries to identify which sample is perceived similar or different. Table 2 shows the summary of LSD test. Result only compares samples within a group not between group in certain LL. Samples with symbol * or # or @ illustrate that those samples are perceived similar. There are only 2 symbol appeared at group A and B. Moreover, group C has one more symbol rather than those group. Implicitly, respondents from group C has better ability to differentiate samples rather than respondents from group A and B. Therefore, the optimum value of T_{sub} can be analysed using information from group C.

Table 2. Summary of LSD test

LL	T_{sub}	Grup		
		A	B	C
82 dB	1 s	*	*	*
	1.4 s	#	#	#
	1.8 s	*	*	*
	2.6 s	*	*	#
	2.8 s	*	*	*
78 dB	1 s	*	*	*
	1.4 s	*	#	#
	1.8 s	#	*	*
	2.6 s	*	#	*
	2.8 s	#	*	*
74 dB	1 s	*	*	*
	1.4 s	#	#	@
	1.8 s	#	#	#
	2.6 s	*	*	*
	2.8 s	#	#	#
70 dB	1 s	*	*	*
	1.4 s	#	*	#
	1.8 s	*	#	@
	2.6 s	*	*	*
	2.8 s	*	#	@
66 dB	1 s	*	*	*
	1.4 s	#	#	*
	1.8 s	*	*	#
	2.6 s	#	#	*
	2.8 s	*	*	#

Prediction of optimum value is shown at Figure 2. It plots subjective preference vs T_{sub}. Subjective preference is normalized of averaged value at certain LL from psychoacoustic test. According to it, all curves have quite similar trend. It reaches peak when T_{sub} value is 1 s and its value tends to decrease as T_{sub} gets larger. However, there is the second highest score of subjective reference at 74 dB. It occurs whenever T_{sub} is 1.4 s with 0.87 of subjective preference.

CONCLUSION

According to result, background and knowledge about Gamelan Degung Sunda is an important factor to determine optimum value of T_{sub}. Experts or musicians statistically have the best ability to distinguish samples rather than another groups.

All subjective preference curves reach peak at T_{sub} = 1 s. Therefore, it may be predicted 1 s as optimum value of T_{sub} for Gamelan Degung Sunda. However, the optimum value might be 1.4 s since the score for subjective preference is around 0.87 but it only applies for Gamelan Degung Sunda with Listening Level 74 dB.

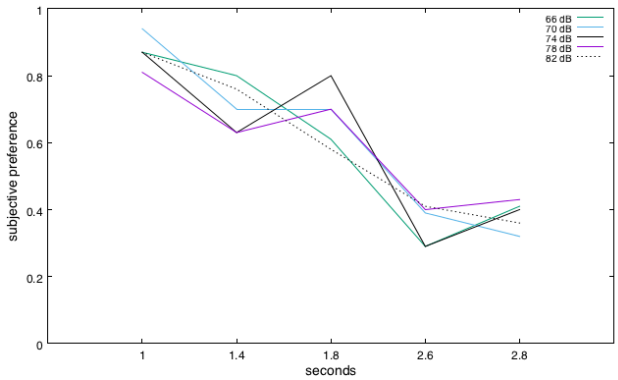

Figure 2. Optimum value of T_{sub} in various LL

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