A SOUND QUALITY CUSTOMIZATION SYSTEM USING PAIRED COMPARISON

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ABSTRACT

This paper proposes a sound quality customization method based on an Paired Comparison interactive genetic algorithm (PC-IGA). A user who is not familiar with music and/or audio devices finds it difficult to customize the reproduction parameters to suit his/her preferences. Our solution is a system that customizes the reproduction parameters for headphone use by an intuitive user input panel; the IGA analyzes the user's inputs and generates the appropriate parameters. The system makes it easy, even for novices, to obtain the preferred sound quality. Here, "sound quality" means a tone. In this paper, the proposed system simplifies the evaluation by using pair comparison. Results of a subjective assessment experiment for one sound sample demonstrate the possibility that the preferred sound quality can be obtained through this system.

1. INTRODUCTION

This paper proposes a system that customizes the reproduction parameters of a headphone-based system so that the user's preferences are satisfied. The common approach to customization is to use of a multiband equalizer where the gain of each frequency band is adjusted. However, it is difficult to employ this approach if the user is not familiar with music and/or audio devices. Our solution is to integrate an paired comparison interactive genetic algorithm (PC-IGA) [1],[2] into a system that uses the user's evaluation input to modify a basic HRTF(Head Related Transfer Function) and obtain the optimum set of reproduction parameters for headphone use. In addition, the proposed system simplifies the user's evaluation by using pair comparison for IGA. The proposed system uses Parametric-HRTF(pHRTF), which is substituted for HRTF in case where the sound sources at 30 degrees off the normal axis is placed through adjusting the parameters of peaking filters and a high shelving filter. Iida et al. [3] shows the effectiveness that the method creating an HRTF by using parametric equalizers is effective. pHRTF enables the frequency response to be varied by varying the parameters of the peaking and high shelving filters. The proposed system uses GA [4],[5] as an optimization method of the parameters. The user evaluates the sound source presented by the system and need not have any knowledge of or experience with music and audio devices. Thus it is considered that the proposed system is effective in that anyone can easily obtain their desired sound quality. We demonstrate the effectiveness of this system through a subjective assessment experiment.

Table 1: Details of the digital filters composing pHRTF

	f_0[Hz]	*gain*[dB]	
HSF	500	7.0	S=0.7
PF1	2900	13.5	Q=1.5
PF2	5200	6.2	Q=2.0
PF3	7800	-2.5	Q=7.0
PF4	8900	9.0	Q=7.0
PF5	10360	-12.0	Q=6.0

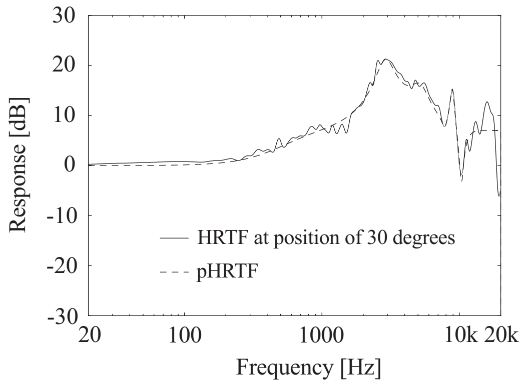

Figure 1: Comparison of HRTF at position of 30 degrees and pHRTF.

2. SOUND QUALITY CUSTOMIZATION SYSTEM USING PC-IGA

The sound quality customization system optimizes the reproduction parameters to realize the desired sound quality based on subjective evaluation values input by the user. This system uses the parameters to design digital filters that are used to convolve the basic sound source and to adjust the sharpnesses of peaks and notches of pHRTF.

2.1 Basic Sound Source

This section describes the basic sound source. Our prior research, including some subjective assessment experiments, showed the desirability of setting the HRTF to yield sound sources at 30 degrees off the normal axis. To simplify the system, we replace the HRTF with some peaking filters and a high shelving filter. Hereafter, we refer to this simplified HRTF as pHRTF. Iida et al. developed a Parametric-HRTF by resolving the amplitude spectrum of HRTF into several peaks and notches and implementing all or some of them as parametric equalizers [3]. This pHRTF simplified by re-

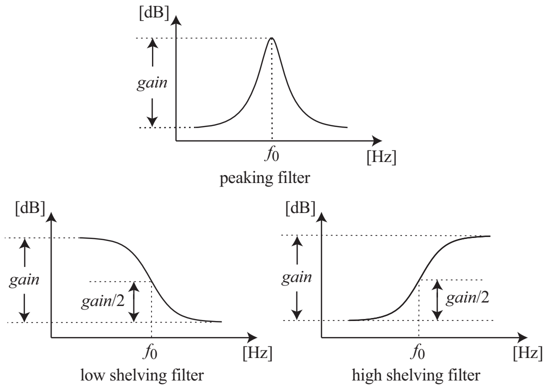

Figure 2: Parameters of peaking and shelving filters.

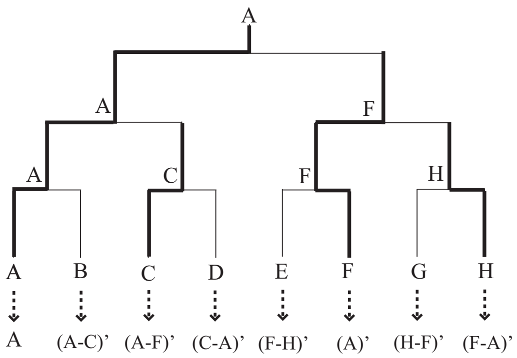

Figure 3: Tournament tree in PC-IGA.

ferring the method of the Parametric-HRTF enables the frequency response to be varied by varying the parameters of the peaking and shelving filters. The details of the digital filters composing pHRTF are shown in **Table 1**. Each parameter in Table 1 is defined in **Fig. 2**. The comparison of HRTF at position of 30 degrees and pHRTF is shown in **Fig. 1**.

2.2 Optimization by PC-IGA process

This section describes the PC-IGA [1],[2] process. PC-IGA(Paired Comparison Interactive Genetic Algorithm) uses a tournament tree and uses the characteristic of the tournament tree in the genetic operation. An example of the tournament tree is shown in **Fig. 3**. From one round to the finals, child individuals are generated through crossover and mutation for winner individuals surviving to the next match in the next round of tournament. The child individuals replace the corresponding loser individuals. In addition, the loser individual in the finals is replaced with mutated champion the individual. For example, A and C win at the one round of the first and the second matches. As a result, B and D which lost to A and C are replaced with the individuals generated through the crossover and mutation of A and C. By repeating such an operation, the finalist (solution candidate) is left as the elite solution of the generation in the next tournament (next generation) .

2.3 System Structure

The flow chart of the system is shown in **Fig. 4** and the search ranges of the parameters of the lower-frequency and the higher-frequency and bit numbers assigned to each parameter are shown in **Tables 2**, and **3** respectively. The flow of the system is shown below.

1. The 1st tournament for the lower frequency parameters is held. Then, the initial individuals (i.e.,the participation population of the tournament) are 4 individuals fixed. The parameters of **Table 3** is set to have the same frequency response as pHRTF.
2. After the champion individual is determined, genetic operator is performed for the parameters of **Table 2** based on the result of the tournament.
3. The 2nd tournament for the lower frequency parmeters is

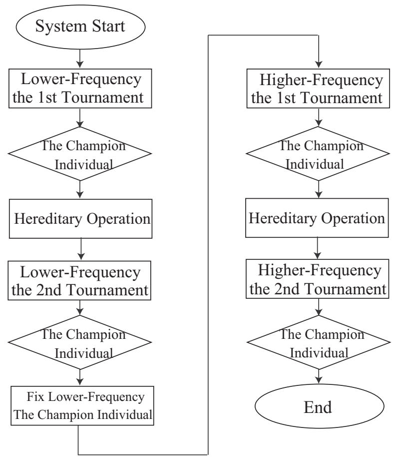

Figure 4: Flow-chart of the proposed system.

Table 2: Search range of the parameters (lower-frequency)

		min	max	bit
LSF	f_0[Hz]	50	200	2
	gain[dB]	-7.5	10	3
PF	f_0[Hz]	200	950	2
	gain[dB]	-7.5	10	3
	Q	0.5	1.5	2

Table 3: Search range of the parameters (higher-frequency)

		min	max	bit
PF1(f_0=2900[Hz])	Q	0.3	1.5	2
PF2(f_0=5200[Hz])	Q	0.3	2.0	2
PF3(f_0=7800[Hz])	Q	0.5	7.0	2
PF4(f_0=8900[Hz])	Q	0.5	7.0	2
PF5(f_0=10360[Hz])	Q	0.5	6.0	2

Table 4: Parameters in PC-IGA

Crossover	one-point crossover
Crossover rate	1.0
Mutation	uniform mutation
Mutation rate	0.01

Table 5: Conditions of subjective assessment

Number of subjects	12
Music sample	I believe(WAV file from CD)
Listening time	15 s
Frequency range	20-20000 Hz
Headphone	MDR-Z600(SONY)

held.

4. After the champion individual is determined, the lower frequency parameters are fixed to those of the champion individual.
5. The 1st tournament for the higher frequency parameters is held. Then, the initial individuals are 8 and those individuals, initial parameter sets are generated at random.
6. After the champion individual is determined, the genetic operator is performed for the parameters of **Table 3** based on the result of the tournament.
7. The 2nd tournament for the higher frequency parameters is held.
8. After the champion individual is determined, the corresponding parameters are the optimum parameters.

Each parameter (crossover, mutation) in PC-IGA is shown in **Table 4**.

3. VERIFICATION OF EFFECTIVENESS

We conduct a subjective assessment experiment (Subjective Assessment Experiment 1) using the proposed system for 20 year old students and another subjective assessment experiment (Subjective Assessment Experiment 2) using the optimum parameters of each subject to demonstrate the effectiveness of the proposed system.

3.1 Subjective Assessment Experiment 1

The conditions of the subjective assessment experiment 1 using the proposed system are shown in **Table 5**. The subjects were 12 men in their twenties. The user interface of the system is shown in **Fig. 5**. From **Fig. 5**, each user only evaluates the sound source with favorite sound quality.

Comparisons of pHRTF and the frequency responses filtered by using the optimum parameters of 5 subjects are shown in **Figs. 6-10**. From **Figs. 6** and **9**, subjects A and D prefer the frequency response with high gain in the low and middle frequency band. From **Figs. 7**, **8** and **10**, subject B, C and E prefer the frequency response that is similar to pHRTF or with a little low gain in the low and middle frequency band. In the middle and high frequency band, each subject prefers various frequency responses. We also asked the subjects if they were satisfied with the sound quality yielded by the optimum parameters. All subjects answered that they were so satisfied.

3.2 Subjective Assessment Experiment 2

We inspect whether favorite sound quality is really provided for a subject by the proposed system. We demonstrate the effectiveness of the proposed system through verifying a significance of preference among some music sources. We use music sources generated by the optimum parameters of each subject in **3.1**. Music sources used for experiment are as follows.

1. Original music source.
2. Music source generated by the parameters of the lower-frequency 2nd tournament's champion individual.
3. Music source generated by the optimum parameters.
4. Music source generated by the parameters of pHRTF.

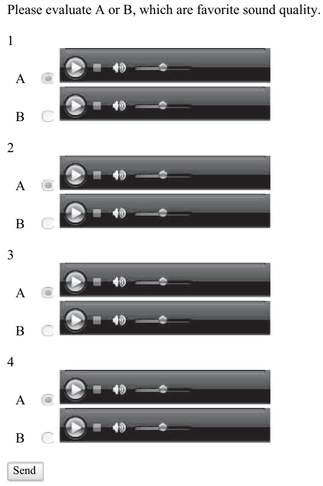

Figure 5: User interface of the proposed system.

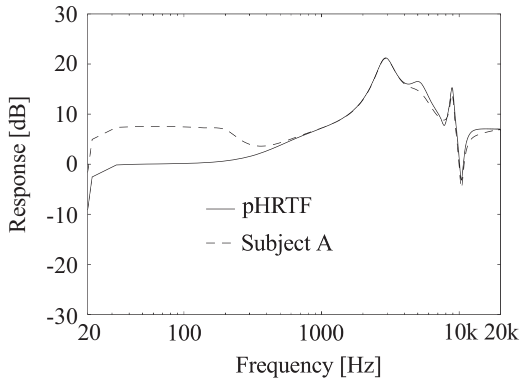

Figure 6: The comparison of pHRTF and the frequency response generated by the optimum parameters of subject A.

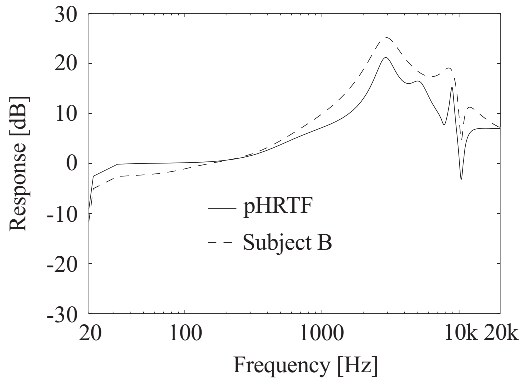

Figure 7: The comparison of pHRTF and the frequency response generated by the optimum parameters of subject B.

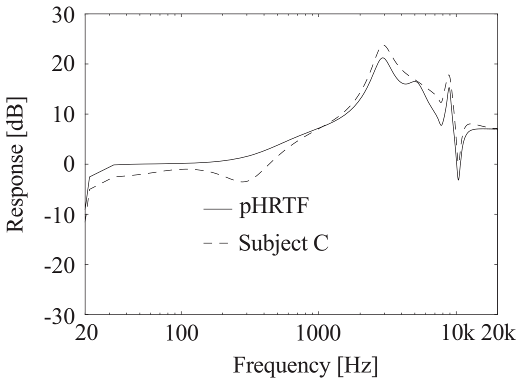

Figure 8: The comparison of pHRTF and the frequency response generated by the optimum parameters of subject C.

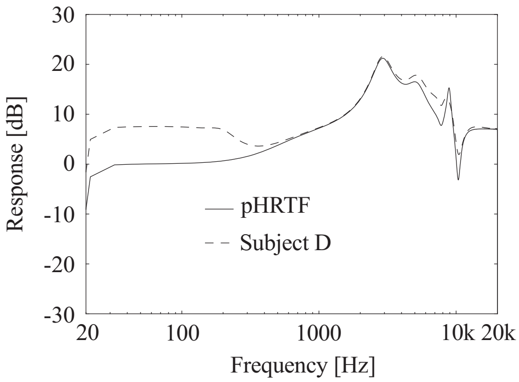

Figure 9: The comparison of pHRTF and the frequency response generated by the optimum parameters of subject D.

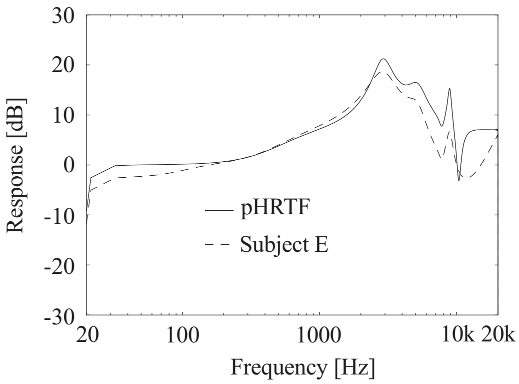

Figure 10: The comparison of pHRTF and the frequency response generated by the optimum parameters of subject E.

We used Scheffe's pair comparison for these four sources. The conditions of the subjective assessment experiment 2 are shown in **Table 6**. Subjects evaluated all combinations of four sources by five points scale (+2 like $\sim$ -2 dislike).

The experiment result is shown in **Fig. 11**. The vertical axis of **Fig. 11** expresses an interval scale, and the bar lengthening up and down of the average mark (95% confidence interval) of each source expresses the acceptance region. When the average mark of a certain source is outside the bar of other sources, significant difference is shown between these samples (reject rate is 5%). From **Table 6**, Source 3 has no significant difference for Source 1, but gets the best evaluation. Hence, the proposed system has the possibility to provide the preferred sound quality for users.

Table 6: Conditions of subjective assessment

Number of subjects	12
Music	I believe(WAV file from CD)
Listening time	15 s
Frequency range	20-20000 Hz
Headphone	MDR-Z600 (SONY)

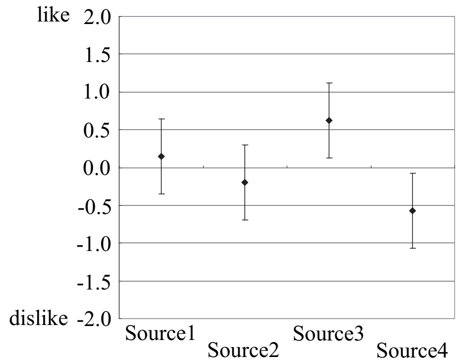

Figure 11: Result of the experiment.

4. CONCLUSIONS

In this paper, we have proposed a sound quality customization system using paired comparison. From verification of effectiveness, the proposed system has the possibility to provide preferred sound sources for each user. We plan to improve the proposed system in order to customize the sound quality more effectively.

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