Augmentation of obstacle sensation by enhancing low frequency component for horror game background sound

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ABSTRACT

Computer games provide users with a mental stimulation that the real world cannot. Especially, horror games are a popular category. Current horror games can provide the user with a visible ghost and the stereo background sound to thrill the user. Inspired by obstacle sense - the ability of blind people localizing themselves only with hearing, a novel method to augment the sense of existence in the game background sound is proposed in this paper. We found that an effective sense can be created by decreasing high frequency component and increasing low frequency component simultaneously.

Categories and Subject Descriptors

H.5.1 [**INFORMATION INTERFACES AND PRESENTATION**]: Multimedia Information Systems – *Artificial, augmented and virtual realities*

General Terms

Experimentation, Human Factors

Keywords

Augmented reality, Obstacle sensation, Game background sound

1. INTRODUCTION

Computer games have been created for almost as long as there have been computers. To some people, computer games are a phenomenon with greater cultural importance than movies or sports. These games combine the aesthetic and the social aspects in a way the old mass media, such as theatre, movies, TV shows and novels do not. Horror computer games are one of the most popular categories which attract users by its psychological thrill. Bio-hazard, Silent Hill etc. are examples of the popular horror games.

The way horror computer games are designed to frighten and scare the gamer are relying on the visual and acoustic element simultaneously. The two elements are working together to elicit the emotional reactions about the upcoming frightening events [1]. The complex interactive soundtracks based on what the players do create an appropriate euphoric atmosphere. Especially, feeling the existence while seeing nothing is maybe the most horrible experience, which is the scope of this paper.

In this paper, first, an overview of the previous studies on obstacle sense is given. Compared with the previous works, we propose and evaluate a novel method to augment obstacle sense making it easier to apply on the horror game sound tracks. The method enhances the low frequency component based on the different frequencies. Finally, we discuss and conclude our proposal with a plan for future work.

2. RELATED WORKS

Humans can perceive the existence and the position of non-sound object aurally, without visual information. This ability is known as "auditory obstacle perception" or "obstacle sense", and was introduced by Diderot in 1749 as "amazing ability" of a blind to judge accurate distance of the object as well as to perceive the presence of object without visual information [2]. After this publication, a significant amount of research has been conducted relating to this ability. Supa *et al*. organized the previous works as two theories; sense of the skin and of the auditory [3]. After the systematic studies, they reported that the factor of the obstacle sense was not due to skin sensation, but resulted from auditory stimuli. Seki *et al*. reported that the change in pitch resulting from the acoustic coloration is an essential factor in perceiving the obstacle [4].

The factors of this perception may include the impression due to the change of acoustic field caused by the reflected sound [5] [6] [7][8]. The reduction in volume due to absorption is another factor [9]. Nowadays, virtual acoustical obstacle can already been aurally presented by sound convolved with acoustic transfer function measured under the environment with obstacle by dummy head microphone [10]. The technique can be applied to the blind mobility aid and orientation training environments for the blind [10].

If the obstacle sense can be applied to the sound track of the horror game to elicit the emotional reactions of the upcoming frightening events, a more euphoric atmosphere can be given to the gamer. However, using a dummy head to record sound is high-cost and hard to apply to the interactive situation such as computer games. Also, obstacle sense ability between the blind and the sighted is quite different. Miura *et al*. indicated that the blind can estimate the obstacle distance more precisely than the sighted. The results also indicated that the sighted tend to focus mainly on the quantitatively represented changes such as pitch and loudness of the sounds, while the blind are inclined to focus not only on the quantitative sound change, but also on qualitative impressions in the sound changes [11].

Previous research has elucidated the principles of obstacle sense with the goal to develop barrier-free technologies for the visually impaired. Unlimited to the welfare technology, our purpose is to "augment" the obstacle sense. The main focus points of our work are: simplification of the principle so that it is easy to apply; possible exaggeration of the effect so that it can be an unnatural yet effective method for the horror games background sound.

3. PROPOSAL

3.1 Principle of our proposal

As mentioned in section 2, there are two main factors for real obstacle sense. One is coloration by reflected sound, and the other is attenuation by shielding (Figure 1).

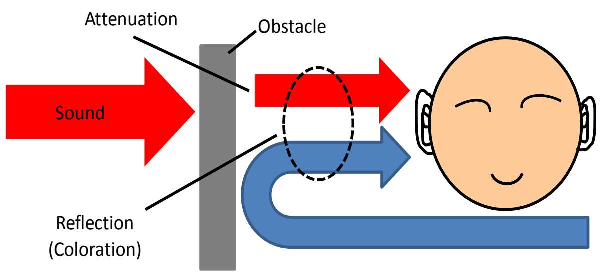

Figure 1. Schematic explanation of obstacle sense. The sound heard by the listener is combined with attenuation and coloration. Both lead to the disappearance of the sound image.

Obstacle sense caused by wall-like objects was mainly studied in previous research. Accordingly, the reflection is set as the contributing factor. Considering our application for the horror game, relatively smaller object should be targeted to express the aural effect. Therefore, attenuation by shielding is set as a fast candidate.

The attenuation is mainly observed by high frequency component since the high frequency sound tends to transmit straight and reflect by the obstacle, while the low frequency sound tends to diffract. This frequency dependency is well known as a natural phenomenon which has also been confirmed by psychophysical experiments [12]. However, to our knowledge, no previous works have extended this effect to the exaggeration of the obstacles sense.

4. EXPERIMENT

4.1 Experiment 1: One parameter: Frequency

4.1.1 Material

Participants: There were N=5 participants (3 female, 2 male) with normal hearing in our experiment. Participants were not aware of the purpose of the experiment before and have not especially mastered the obstacle sense. The mean age of participants was 24.4 with a standard deviation of 2.07.

Experiment parameters:

Frequency: 400Hz, 800Hz, 1600Hz, 3200Hz, 6400Hz, 10000Hz

Volume: Sound intensity level was set as constant (comfortable level 45 to 60 dB SPL)

Direction: Left, Right

The parameter frequency here refers to the cut-off frequency of the low pass filter. The 10000 Hz cut-off frequency parameter was set as a standard sound.

Apparatus: Open type headphone STAX SRM-007tA was used. As a sound stimuli-pink noise (sampling rate at 44.1 KHz) was generated and modified with different experimental parameters by puredata. The order of each sound stimulus was randomly arranged.

4.1.2 Procedure

The experiment was carried out in a quiet room (Figure 2). Before starting the experiment, the participants received instruction as to what is obstacle sense. They were asked to close their eyes, and feel the sound variation by approaching both side of the ear with the hand respectively. After understanding the obstacle sense, they were asked to wear the headphone, and practiced several questions in order to get familiar with the software environment before the formal experiment.

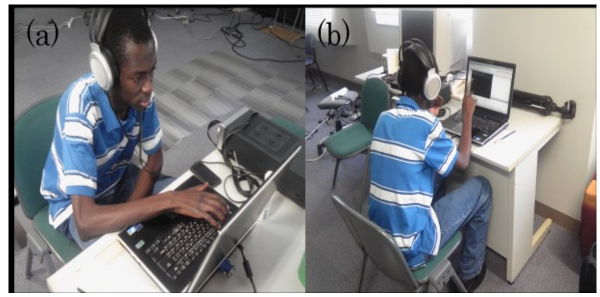

Figure 2. Overview of the experiment

One element among the 3 parameters was chosen randomly and was assumed as one stimulus trial. First, the standard sound stimulus stated in section 4.1.1 was binaurally presented to the subject. After that the sound was gradually changed by applying the low pass filter. The change took 0.5s, and the duration of the stimulus was 4s. After each trial, the sound returned to the standard sound in another 0.5s (Figure 3).

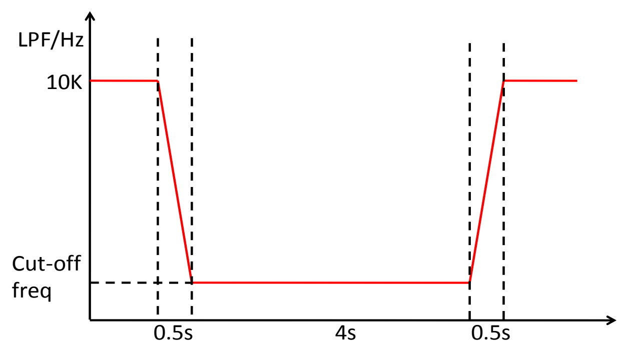

Figure 3. Schematic representation of experiment 1 procedure. The horizontal axis indicates time. The vertical axis indicates the parameter- cut-off freq

The participants were required to respond to the following two questions by keyboard after each sound stimulus:

Direction: From which direction do you feel an object is approaching?

Obstacle sensation certainty: How certain that you feel the existence of an obstacle?

The obstacle sensation certainty was evaluated by 1-5 scale from “No feeling” to “Strongly felt”.

There were 108 trials (=6(frequency) ×1(volume) ×2(direction) ×9(repeat count)) in this experiment. The whole experiment took about 25 minutes.

After the experiment, the participants were asked to answer a questionnaire about general personal information, and their opinion or suggestion regarding the experiment.

4.1.3 Results and Discussions

The results are shown in Table 1. The correct answer rates and the average evaluation of the obstacle sensation certainty were higher as the cut-off frequency decreases. As expected, the correctness rate of the standard sound stimulus was about 50%. The correctness rate of the 400 Hz has reached to 91%(standard deviation (SD) = 14%) with an average evaluation of the certainty 3.54 (standard deviation (SD) =1.61).

Table 1. Results of experiment 1

Cut-off frequency(Hz)	Rates of correctness	Obstacle sensation certainty
400	91%	3.54
800	88%	3.32
1600	88%	2.92
3200	87%	2.27
6400	51%	1.37
10000	48%	1.30

The results of the experiment show that as the cut-off frequency decreases, the subject perceives the obstacle sense stronger, although 400 Hz cut-off frequency might not feel natural.

Two possibilities can be indicated. First, the sound quality variation was perceived as existence in the experiment. Second, decay of the total sound volume led to the obstacle sense. The latter possibility has been reported by Matsuo *et al.* with different method [13], with which the participants mistakenly perceived the presence of the obstacle by presenting noise from all directions except the obstacle direction. Hence, the question is, in the perception of obstacle, which one, the quality (decrease of high frequency component) or quantity (decrease of total volume) plays the major role. Also, considering the usage of speaker in the real gaming situation, we would like compare the 2 conditions of earphone and speaker.

Consequently, the second experiment was conducted.

4.2 Experiment 2: Two parameters: Frequency and Volume

4.2.1 Material

Participants: There were N=6 participants (2 male, 3 female) who are different from the experiment 1. The mean age of participants was 26.0 with a standard deviation of 2.35.

Experiment parameters:

Frequency: 400 Hz, 2000 Hz, 10000 Hz

Volume: -10 dB, Constant, and +10 dB.

Direction: Left, Right

Conditions: Speaker, Earphone (The volume of the speaker and earphone was set to the same sound level.)

For example, 400 Hz with +10 dB means that the sound was low-passed with cut-off frequency of 400 Hz, and the volume was increased +10 dB, resulting in enhanced low frequency sound. On the other hand, if the frequency was 10000 Hz and the volume was -10 dB, the sound was not low-passed and the volume was decreased 10 dB.

Apparatus: The apparatus was the same as experiment 1 except for the sound stimuli. Light music named-«NAIHOSURUDAICHI» (name in Japanese) was used as the sound stimuli.

4.2.2 Procedure

In the speaker condition, height of speakers was adjusted equal to the participants' ear. The participants tested each of the two conditions. The order of conditions was randomized so that each condition was performed first by half of the participants. The total procedure and the experiment environment were the same as experiment 1.

There were 54 trials (=3(frequency) ×3(volume) ×2(direction) ×3(repeat count)) in each condition. Thus, the total number of the trials was 108(=54×2(condition)).After the experiment, the same questionnaires were asked.

4.2.3 Results and Discussions

Table 3. Speaker: average evaluation of obstacle certainty and correct answer rates for the direction

Cut-off frequency(Hz) \ Volume(dB)	Certainty average			Correctness rate		
	-10	Constant	+10	-10	Constant	+10
400	2.89	2.70	3.90	57%	73%	87%
2000	1.97	2.47	3.90	67%	67%	77%
10000	2.33	2.47	4.53	47%	57%	77%

Table 4. Earphone: average evaluation of obstacle certainty and correct answer rates for the direction

Cut-off frequency(Hz) \ Volume(dB)	Certainty average			Correctness rate		
	-10	Constant	+10	-10	Constant	+10
400	3.17	2.87	4.17	73%	50%	40%
2000	2.50	2.37	3.97	77%	43%	43%
10000	2.60	2.00	4.07	60%	50%	57%

Table 3 and Table 4 show the results under the conditions of speaker and earphone.

Our expectation from the result of experiment 1 was as follows; if the obstacle sense was perceived by the change of quantity (decrease of total volume), increasing volume (+10 dB) should effect negatively to the obstacle sense. On the other hand, if the obstacle sense was perceived by the change of quality (decrease of high frequency component), combination of increasing volume and decreasing high frequency component (+10 dB and 400 Hz) should generate clearer obstacle sense.

The result was somewhat contradictory. In both speaker and earphone case, the obstacle certainty was increased when the total volume was increased (+10 dB). It means that decrease of total volume itself was not the main factor of the obstacle sense. However, it does not mean that decrease of high frequency component is essential, since the obstacle certainty was increased when only the total volume was increased (10000 Hz, +10 dB).

From these result, we speculate that there are two contributing factors in the obstacle sense. One is *increase*, not decrease of total volume, and the other is decrease of high frequency component. In this experiment, 10 dB volume changes might be too large so that in all +10 dB cases, the obstacle sense became clearer.

On the other hand, there was a significant difference on the correctness rate between the speaker and earphone. In the speaker case, *increasing* total volume always increased the correctness rate whereas in the earphone case, *decreasing* total volume always increased the correctness rate. Currently we do not have explicit reasoning, but we are considering two possibilities. One is that in the speaker case, we could hear constant environmental noise, so that decrease of high frequency component was not clearly perceived, and the participants relied on total volume change. The other is that in the speaker case, the sound might have elicited tactile sensation by acoustic radiation pressure [14], which might have been an additional cue for obstacle sense. To figure it out, we put scarf around the neck under speaker condition, and we observed that the obstacle sensation was weakened.

5. CONCLUSION AND FUTUREWORK

In this paper, we proposed a novel method to present a more effective obstacle sense by decreasing high frequency component and increasing low frequency component simultaneously. To evaluate our proposal, two experiments were conducted. The results suggested that increase of total volume and decrease of high frequency component are two contributing factors for the obstacle sensation. We also observed difference between speaker and earphone, which might be explained either by surrounding environmental noise or tactile sensation generated by acoustic radiation pressure, but further investigation is needed.

Actually, these results can be used in any type of virtual environment (VE). Horror game sound is just our interest. After conducting the fundamental experiments, we want to construct a horror video game system. The sound effect that proposed in this paper will be embedded. Other factors for the horror contents, such as visual effect and tactile stimulation will also be incorporated, and combinational effects will be evaluated.

6. ACKNOWLEDGEMENT

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