Proposal for an Interactive 3D Sound Playback Interface Controlled by User behavior

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Abstract. Our study introduces an interactive 3D sound playback interface system that is controlled by the user's behavior. It consists of an Android terminal, stereo headphone, and Nintendo Wii Balance Board. Traditional binaural audio systems can only deal with simple fixed playback conditions. On the other hand, our system assumes that the user is continuously moving. When a user who is riding on the Wii Balance Board moves his/her body, binaural sounds during playback are generated according to changes in his/her center of gravity. To implement the system, we have prepared a set of twenty-four acoustic signals for embedding into the system. If the user's center of gravity corresponds with one of the twenty-four regions, an acoustic signal recorded in advance corresponding to that region is reproduced for the user. We experimentally evaluate how accurately a user can judge the position of a sound source. Experimental results prove the proposed system yielded significantly higher locational accuracy than the original binaural system.

Keywords: Binaural stereo sound, Wii balance board, Interactive sound interface.

1 Introduction and Overview of the Proposed System

We have developed an interactive 3D sound playback system that is controlled by user movement. Figure 1 shows an overview of the system. It consists of an Android terminal (main controller), stereo headphones, and a Nintendo Wii Balance Board[1] (for detecting the position of a user's center of gravity). Communication is via Bluetooth wireless connection.

Binaural recording is a method of recording audio signals using two microphones. It is meant to produce the sensation of a 3D acoustical space during headphone playback. Traditional binaural audio systems, used primarily for high-fidelity recording of natural sounds, are equipped for simple, fixed playback conditions, and are insensitive to the user's movements. In this paper, we propose a new binaural system that is sensitive to continuous motion by the user. By shifting his/her center of gravity over the Wii Balance Board, the user controls the perceived location of the binaural sound source. For example, when the user moves to the left, the perceived sound source moves to his/her right.

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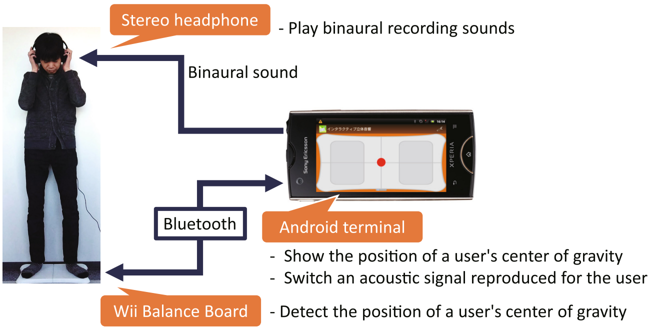
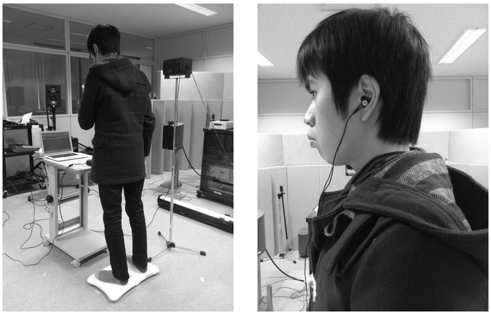


Fig. 1. Overview of the proposed system



(a) Complete system (b) Use of stereo-ear-microphone

Fig. 2. Setup for binaural recording with a stereo-ear-microphone

To implement our system, we first used a stereo-ear-microphone (Roland CS-10EM[1]) to binaurally record a set of twenty-four acoustic signals for embedding. Figure 2 shows the setup of these binaural recordings.

If the user's center of gravity corresponds with one of the twenty-four regions of the Wii Balance Board surface (Fig. 3), the acoustic signal corresponding to that region is reproduced for the user. The system can switch seamlessly between signals via look-ahead processing and triple buffering which enable switch between the signals without gaps in playback.

2 Evaluation of the Proposed System

We experimentally evaluated how accurately a user could judge the position of a sound source using our system. Figure 4 provides a snapshot of our experiment.

[1] http://www.roland.com/products/en/CS-10EM/

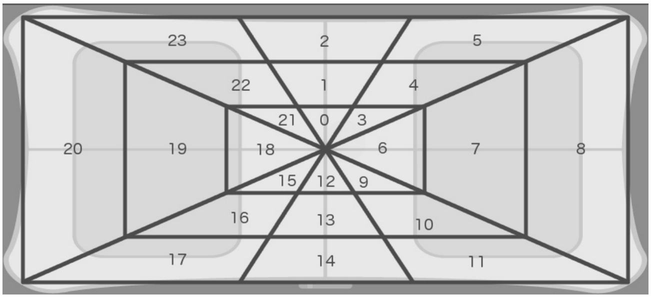


Fig. 3. Scheme for 24 regions of the Wii Balance Board surface

Fig. 4. A snapshot of our experiment using the proposed system

For the test signals, two kinds of sounds were used; a simple beep, and a submarine sonar pulse. Each signal was recorded at each of the 24 board positions, and the resulting 48 embedded signals were played back in random order for test listeners (a group of 15 students).

To measure how accurately participants could estimate the position of the sound source, we asked them to select from eight candidate positions for the sound source; (1) Left front, (2) Front, (3) Right front, (4) Left, (5) Right, (6) Left back, (7) Back, and (8) Right back. They attempted to identify the position of the sound source as they listened to the binaural signals and shifted their bodies freely on the Will Balance Board.

We also conducted exit interviews with the test participants, to get a better indication of how intuitive the interface seemed to them. We asked the participants to answer the following questions on a five-point scale:

Q1) How confident did you feel about your location estimates? (1: not confident – 5: very confident)

Q2) How much delay did you perceive delay during sound reproduction? (1: a lot of delay – 5: little or nodelay)

Q3) To what degree did the reproduced sounds seem natural? (1: not at all – 5: very much)

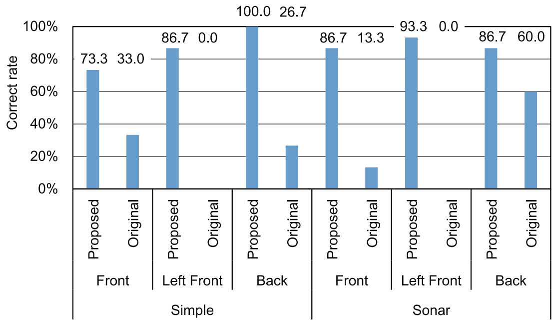
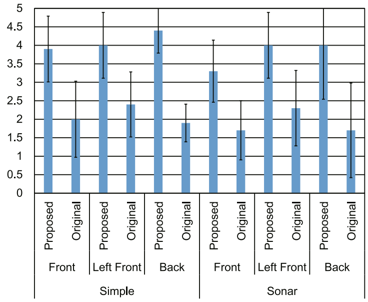
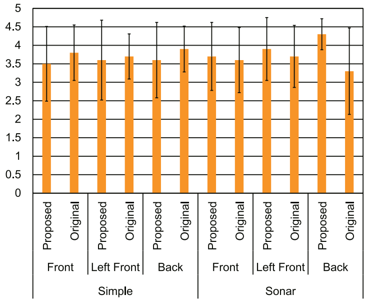


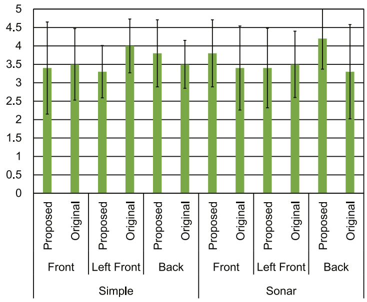
Fig. 5. Comparison of sound source location accuracy between the proposed system and a traditional binaural sound system



(a) Q1: Confidence



(b) Q2: Delay



(c) Q3: Naturalness

Fig. 6. Results for interview questions

Figure 5 shows the location accuracy rates for the proposed system and for a traditional system, in which user motion causes no shift between signals. The bars indicate the average accuracy rate for the 15 test participants. Note that the proposed system yielded significantly higher locational accuracy than the original binaural system.

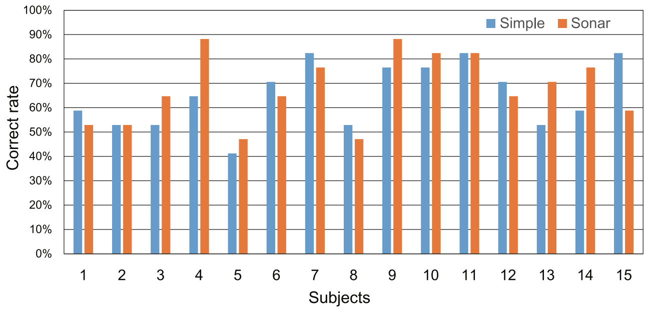


Fig. 7. Correct rates of for each subject in using the proposed system

The results of our interview questionnaire are provided in figure 6(a). Note that the proposed system significantly improved user confidence in locating sound sources. Also note that there were no significant or conclusive changes in users' perceptions of sound delay (Figure 6(b))) or naturalness (Figure 6(c)). This confirms that the additional processing of the proposed system did not adversely affect users' experiences.

Figure 7 shows the average accuracy rate for each subject. Note that individual differences did occur, suggesting the need for further investigation of personal differences in binaural perception.

3 Conclusions and Future Work

We have proposed an interactive binaural sound reproduction system in which the user can better sense the position of sound sources. The system can switch seamlessly between locationally indexed binaural signals according to changes in the user's center of gravity. Experimental results showed that the proposed system significantly improved users' ability to locate the position of a sound source, without affecting playback quality.

At present, our system detects user position based only on detection of their center of gravity. To make the system simpler and more flexible with regard to movement, we are now considering integration of sensory input from the on-board accelerometer of our Android device. We also plan to carry out deeper analysis of spatial listening behavior among users.

References

1. Nintendo, Wii Balance Board Operations Manual (2008), `http://www.nintendo.com/consumer/downloads/wiiBalanceBoard.pdf`