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研究課題名（和文）Saund: Simulation of auditory near-field distance

研究課題名（英文）Saund: Simulation of auditory near-field distance

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研究成果の概要（和文）：The continuous effort of the researchers and their periodic communication have been reflected in the smooth progress of the project, arriving to the end of it according to the initial plan.

研究成果の学術的意義や社会的意義
With the tools produced in this research it is possible to make a sound to appear as coming in different directions at a short distance from a listener in a virtual environment. This is an improvement of existing methods which only allow the correct presentation of sound a large distances.

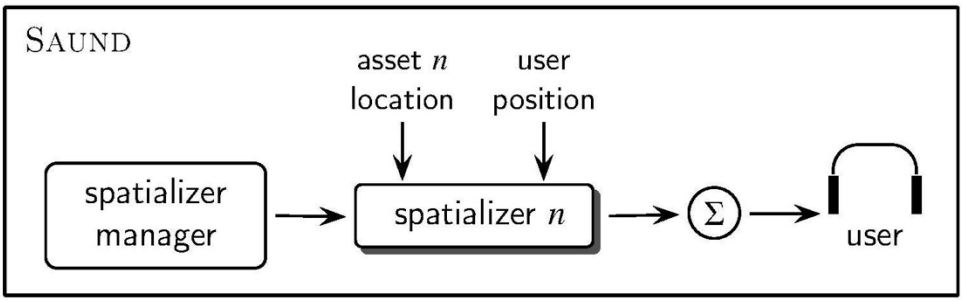
研究成果の概要（英文）：The continuous effort of the researchers and their periodic communication have been reflected in the smooth progress of the project, arriving to the end of it according to the initial plan. Besides the development and evaluation of several sound spatializers, the effort of the two laboratories in the last year was reflected in the publication of two articles in international peer-reviewed conference proceedings, three articles in peer-reviewed journals, and the submission of one additional article to an international conference. In total, we published our results in 10 international conferences and 3 peer-reviewed journals. We also published the code of 4 libraries for sound spatialization related to our project.

研究分野：Virtual Sound

キーワード：Virtual Reality　Spatial sound　3D sound　Headphone display　Head-mounted display

１．研究開始当初の背景

This project, SAUND, aims to develop a sound spatializer (a software program) that can be used with Head-Mounted Displays (HMD). An HMD is a device featuring 3D displays that is usually worn as a helmet or pair of glasses. The proposed spatializer would be able to simulate not only distance changes of remote sound sources (as current spatializers do) but those produced in the near proximity of the user. Specifically, we plan to develop a prototype of such spatializer as depicted in the figure below:



Conservative estimates [1] put the number of HMD units sold by 2020 around 25 million. This multi-billionaire market would increase the demand for immersive contents not only visually, but also auditory, tactile, etc. Auditory, i.e., the sense of hearing, is arguably the second most important modality of perception.

In contrast with the verisimilitude of the visual images obtained with HMDs, the projection of auditory images still faces many hurdles preventing such realism. For example, binaural recordings (recordings made with two mikes fit into a surrogate of the listener: another person, mannequin, etc.) allow impressive auditory illusions which also capture the room characteristics where the recording was made. However, situations arise where such recordings become impractical as in the case of virtual worlds where the interactions of agents (inhabitants, assets, etc.) are difficult to predict.

Although the angle from which a sound is being projected is relatively easy to simulate, its auditory distance constitutes an elusive problem. Several techniques have been proposed to solve it: simulating changes with monaural intensity (i.e., changing the sound level on both ears by the same amount) [2]; manipulating the acoustic energy traveling directly from the sound source to the listener's ears and the given by other paths (bouncing against walls, etc.)— direct-to-reverberant energy ratio [3]; computing a Distance Variation Function (DVF) [5], i.e., a function describing changes in the filtering effect of the ears, head, and upper body (Head-Related Impulse Responses—HRIRs) when a sound source moves from far- to near-field; decomposing HRIRs into spherical harmonics (a mathematical way to describe a sound field) [4]; interpolating previously captured HRIRs in the near-filed [6]; etc. To complicate this problem, when a listener is in the near-field of a source (i.e., at a relatively short distance) or in the proximity of walls, monaural intensity changes are no longer adequate. Furthermore, distance judgements of virtual stimuli in the near-field tend to be overestimated by listeners, but the causes of such error are currently undetermined.

The purpose of this research is to bridge the gap between realism of visual and auditory displays in HMDs, especially for near-field sources. Since headphones are the de facto reproduction apparatus for HMDs, in this research, we will focus on the Simulation of AUditory Near-field Distance (SAUND) on headphone (binaural) reproduction.

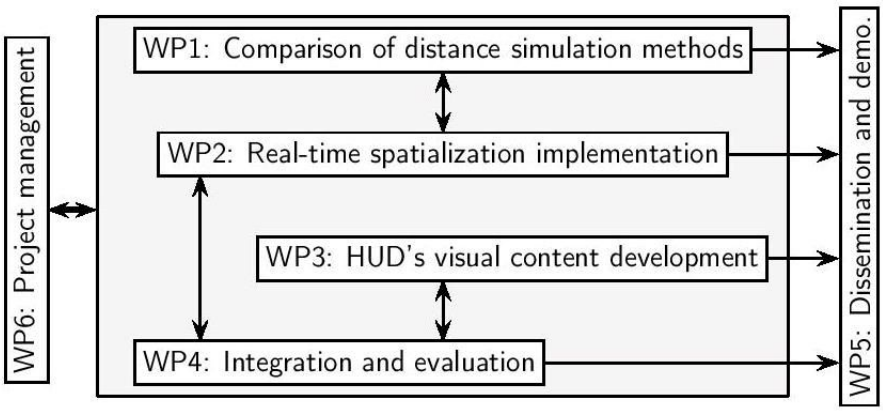
[1] B. Intelligence. The virtual reality report: Forecasts, market size, and the trends driving adoption. Technical report, 2015.
[2] D. H. Mershon and L. E. King. Intensity and Reverberation as Factors in the Auditory Perception of Egocentric Distance. *Perception & Psychophysics*, 18(6):409–415, 1975.
[3] P. Zahorik, D. S. Brungart, and A. W. Bronkhorst. Auditory Distance Perception in Humans: A Summary of Past and Present Research. *Acta Acustica united with Acustica*, 91(3):409–420, June 2005.
[4] M. Pollow, K.-V. Nguyen, O. Warusfel, T. Carpentier, M. Müller-Trapet, M. Vorländer, and M. Noisternig. Calculation of head-related transfer functions for arbitrary field points using spherical harmonics decomposition. *Acta acustica united with Acustica*, 98(1):72–82, 2012.
[5] A. Kan, C. Jin, and A. van Schaik. A psychophysical evaluation of near-field head-related transfer functions synthesized using a distance variation function. *J. Acoustical Society of America*, 125(4):2233–2242, 2009.

[6] *J. Villegas. Locating virtual sound sources at arbitrary distances in real-time binaural reproduction. *Virtual Reality*, Oct 2015.

2．研究の目的

This 3-year project aims to build the next generation of sound spatializers to be used in conjunction with Head-Mounted Displays (HMDs) in Virtual Reality (VR) environments. As a result of this project, a prototype of a real-time virtual sound spatializer which allow distance control for binaural reproduction will be implemented. This proof-of-concept would let us evaluate the accuracy of the spatialization methods especially on the near-field and close to virtual walls. By demonstrating its feasibility and benefits, we expect that the general public take greater interest on the introduction of spatial sound along with visual 3D-technologies.

3．研究の方法



Saund project comprises six work packages (WP) as illustrated in Figure 2. These WPs correspond to different aspects of the project, concretely, WP1 comprises the subjective evaluation of different methods used for near-field localization of virtual sources.

The real-time implementation of the spatializers (on Pure-data programming language) are grouped in WP2, tasks related to the development of visual contents for HMD visualization (developed on Unity) will be conducted in WP3, while WP4 will cover the integration of visual and audio parts, as well as its evaluation.

Dissemination and demonstration tasks are contemplated in WP5, and the administrative tasks to guarantee the normal development of the project (monitoring, coordination, progress meetings, technical progress, objective achievement, financial issues, communication, quality assurance and punctuality of reports and demonstrations) are contained in WP6. Work packages 1, 2, 4, and 6 will be led by Assoc. Prof. Julian Villegas, whereas WP3 and WP5 by Senior Assoc. Prof. J. Huang.

4．研究成果

[1] Trans: Transaural object for Pure-data
[2] Sound spatialization by equalizing filters and side grouping
[3] A Pure-data object for distance controlled sound spatialization
[4] API for audio spatialization in near field on Unity engine

５．主な発表論文等

〔雑誌論文〕（計 3 件）

〔学会発表〕（計 10 件）

〔図書〕（計 0 件）

〔産業財産権〕
○出願状況（計　0　件）

名称：
発明者：
権利者：
種類：
番号：
出願年：
国内外の別：

○取得状況（計　0　件）

名称：
発明者：
権利者：
種類：
番号：
取得年：
国内外の別：

〔その他〕
ホームページ等

http://onkyo.u-aizu.ac.jp/saund/

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