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S. Husung / S. Metag / G. Höhne / C. Weber

Auralisation of technical systems in VR

Introduction

Virtual Prototyping supports the early verification of product properties as well as the communication about the new product, based on digital prototypes. A very important product property which is coming into the focus of investigations is the acoustical product behaviour. Therefore, an increasing number of empirical, analytical and numerical investigations are performed to ascertain and assess the sound of new products.
At the Competence Centre Virtual Reality in Ilmenau a new audiovisual VR-System was installed in order to combine stereoscopic projection with acoustical wave-field synthesis [7]. So it is possible to auralise the complete sound field in the user area with the advantage that all users, independent of their position, have a correct sound impression.
The task now is to develop models to auralise the acoustical behaviour of technical systems and to introduce them into practical development processes. Base is the wave-field synthesis technology, additionally considering functional properties and sound radiation properties like directional characteristics. First models were developed successfully to test the coupling of stereoscopic projection and wave-field synthesis [2].
This paper describes a new approach for the 3D-auralisation which is based on the so-called monopole synthesis [1]. Here, the sound field of an object is represented by a small number of individual monopole sources (point sound sources). In order to use this approach, a complex sound field around a real object is calculated back to several monopoles which easily can be auralised with wave-field synthesis. The superposition of the monopoles reproduces the directional characteristic of the original object.

Concept

For the analysis of audiovisual product properties in virtual environments models are necessary which describe the geometrical, functional and acoustical properties and their relations with sufficient accuracy. Furthermore, the models have to comply with requirements of real-time applications. The geometrical representation is done by using a scene-graph representation. The appropriate product behaviour can be described in a behaviour model and coupled with geometry [6]. For the acoustical product behaviour the direct and indirect sound radiation has to be ascertained (see figure 1). Because of the geometry and the position of the primary sound sources in the structure each component has a sound radiation with a directional characteristic.

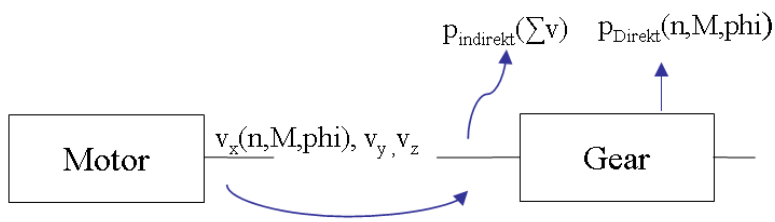

Figure 1: Direct and indirect Sound-Radiation

For the auralisation of objects with a known directional characteristic using wave-field synthesis two main concepts exist:

- Adaption of the wave-field synthesis algorithms [5]
- Representation with a model based on monopole sources describing the characteristic via superposition of several point sound sources

The first concept enables a good reproduction of the characteristic. Considering the tracking data it enables also a good reproduction above the aliasing frequency [7]. But for this method the known characteristic in the VR-model has to be transferred to the wave-field synthesis renderer with special algorithms synchronised to the position of the virtual model and the acoustic data. The second concept, also called monopole synthesis [1], has the advantage to represent the behaviour using a small number of simple monopole sources direct in the scene-graph representation together with the geometry. It is also possible to use the standard wave-field synthesis algorithm for the reproduction. The disadvantage of the second method is the lower accuracy of reproduction, because it is not possible to represent a complex radiation exactly only based on a small number monopoles. For the investigations described below the second method was used.

The idea of the monopole synthesis is to calculate positions and complex amplitudes of a small number of monopoles based on the known directivity characteristic of an object [3] (see figure 2). The approach based on the superposition of monopole sources (point sources):

$$p_A = \sum_{i=0}^{n} A_i \frac{e^{-ikr_i}}{4\pi r_i}$$

With A_i complex amplitude, r_i distance between the monopole and the reproduction point.
Figure 2 shows the superposition of three monopoles in the inner of a sphere. Each pressure p_A on the sphere is the sum of the three monopoles multiplied by the Green's function depending on the distance between the two points and the frequency.
The raw data bases on simulations or measurements.

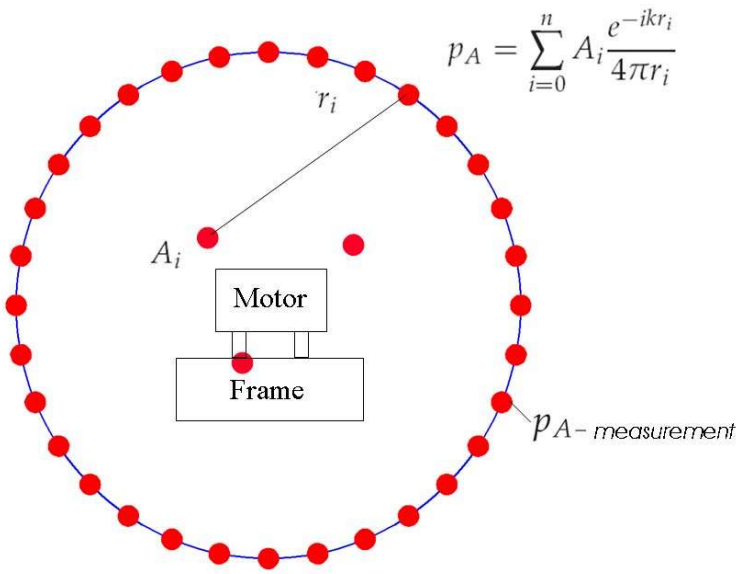

Figure 2: Principle of monopole-synthesis, shown for the example of a motor

For the detection of the complex amplitudes several methods can be used, like pseudo-inverse or minimum error between original and reproduced sound field. The method of the minimum error

offers the best results for the accuracy [8].

$$J(A) = \sum_{m=1}^{M} \left(p_{A-reprod}(r_m) - p_{A\_vorh}(r_m) \right)^2$$

The investigation has been done with a two-way loudspeaker (figure 3). Using a one-microphone sphere array [4] it was possible to measure the characteristic of the loudspeaker with a white-noise stimulus.

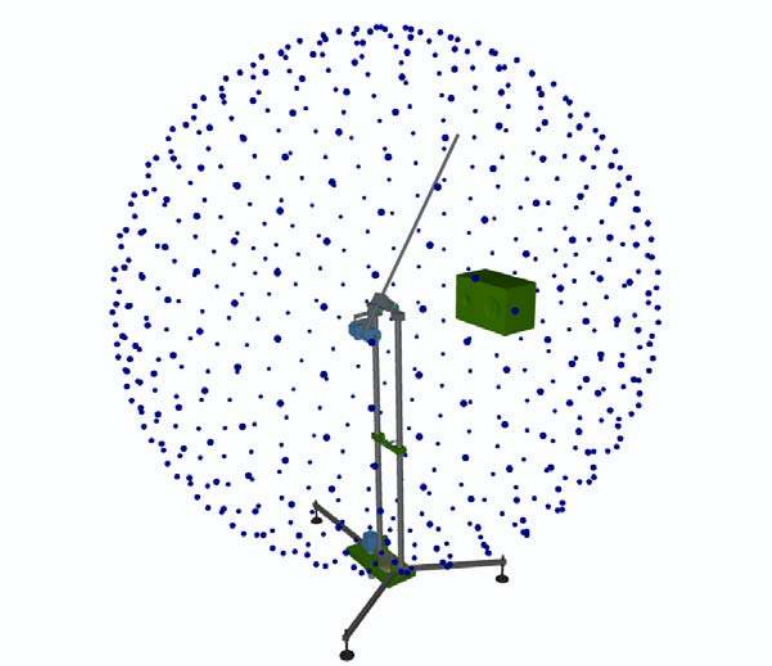

Figure 3: Measurement setup

The calculation was done in Matlab based on algorithms of Giron [1] and Schlesinger et. al. [4] and for the real-time code in native C++. Here for each relevant frequency a matrix is calculated which represents the transformation of the sound field on the sphere surface to the monopole sources.

Figure 4 shows the comparison of the original (left) and the reproduced (right) data for the sound field at 960Hz [8] plotted against the azimuth and elevation angle.

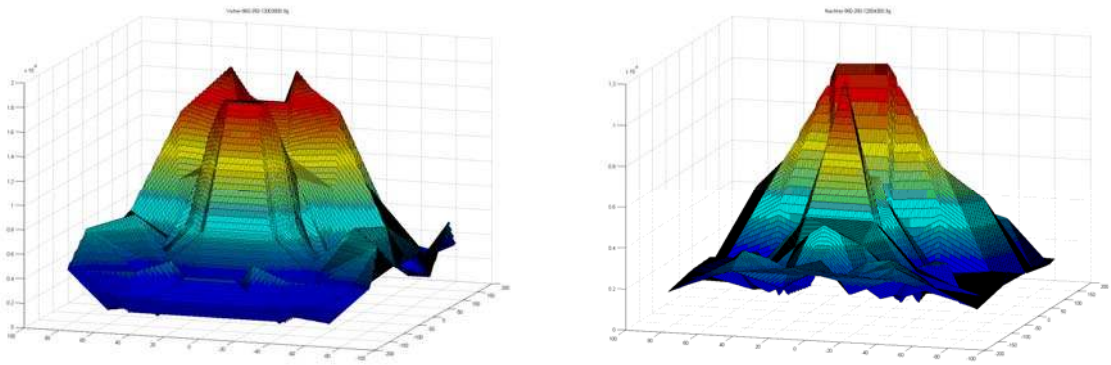

Figure 4: Measured and reproduced characteristic of the two-way loudspeaker

The verification in the VR-system was done with a model of the loudspeaker and eight monopole sources. The reproduction in the audiovisual VR system worked well. It was possible to identify the characteristic in different frequency ranges. The investigation showed, however, that it was not possible to reproduce the characteristic exactly. The problem might be the position of the monopole sources or a latency between the different sources.

Summary

In this paper an approach was presented to reproduce a 3D sound field of complex sources with wave-field synthesis by superposition of a small number of monopole sources. The aim is to auralise a pre-simulated or measured sound field of technical systems in virtual environments. The principle was demonstrated with a two-way loudspeaker. Further applications now are sound and noise analysis of machines and cars.

References:

[1] Giron F., “Investigations about the directivity of sound sources”, Verlag Shaker, Aachen 1996

[2] Höhne G., Husung S., Brix T., Brix S., Lotter E.: “Virtual Prototyping of technical products using a new audiovisual VR system“, 19th International Congress of Mechanical Engineering 2007

[3] Vorländer M., Auralization: Fundamentals of Acoustics, Modelling, Simulation, Algorithms and Acoustic Virtual Reality. Springer Verlag, 2008

[4] Schlesinger A., Galdo G.D., Albrecht B; Husung S: Holographic sound field analysis with a scalable spherical microphone array. Proceeding of Audio Engineering Society (2007)

[5] Baalman M: swonder3Dq: Auralisation of 3D objects with Wave Field Synthesis. 4th International Linux Audio Conference, April 27-30, 2006, ZKM, Karlsruhe

[6] Shen, Q.; Grafe M.; Gausemeier J.: Systemkomposition mechatronischer Prototypen in virtuellen Umgebungen. 6. Paderborner Workshop Augmented & Virtual Reality in der Produktentstehung, Heinz Nixdorf Institut, Universität Paderborn

[7] Melchior F., Sladeczek C., de Vries D., Fröhlich B.: User-dependent optimization of wave field synthesis reproduction for directive sound fields, 124th AES Convention Amsterdam, 2008

[8] Husung S., Metag S., Weber C., Höhne G., Krömker H.: Repräsentation akustischer Produkteigenschaften in virtuellen Umgebungen. 5. Fachtagung "Virtual Reality und Augmented Reality zum Entwickeln, Testen und Betreiben technischer Systeme" 2008

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