

StiffNeck: The Electroacoustic Music Performance Venue in a Box

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ABSTRACT

StiffNeck is a tool for the auralisation of electroacoustic music performance venues based on measured room impulse responses. It has been developed to support *in situ composition*, a particular approach towards creating site-specific electroacoustic music works. This compositional practice tries to take maximum advantage of the particularities of irregular loudspeaker configurations and their interaction with the acoustics of the room. StiffNeck can also be used to rehearse acousmatic performances, to test sound rendering with standard spatialisation techniques using regular loudspeaker configurations or to produce artificial sonic spaces in the context of studio work. StiffNeck comes with a large set of room impulse responses covering various loudspeaker configurations measured with an extensive array of microphones in KUG's *György Ligeti Hall* in Graz. In addition to the convolution based auralisation, StiffNeck provides geometric representations of the loudspeakers, measurement positions, and the hall which can be used for purposes of visualisation but also for performing geometric calculations informing sound synthesis and projection. StiffNeck has been used to produce a variety of *in situ* compositions and has been evaluated informally at several occasions in various ways. The open source tool is available as standalone application and as a SuperCollider Quark.

1. INTRODUCTION

Modern venues for the performance of electroacoustic music, such as IRCAM's *Espace de projection*, SARC's *Sonic Lab*, ZKM's *Kubus*, IEM's *Cube*, or KUG's *György Ligeti Hall* provide composers with large numbers of loudspeakers. Some of these venues also allow for variable and unconventional loudspeaker configurations. This is especially the case for the *György Ligeti Hall*, which hosts more than 100 permanently installed speakers. 33 of them can be positioned and oriented by motorised control, allowing for a complete change of configuration in less than two minutes. Composing music to be performed in such a venue offers exciting and often unique artistic possibilities. However, actually taking advantage of this potential

is difficult in practice. This is due to the quite limited access composers usually have to those venues. Exploiting the possibilities of such complex spaces takes time, especially if it involves the design of a loudspeaker configuration in the first place. Once a distinctive configuration has been created, its possibilities need to be explored empirically as part of the compositional process. The interaction of a particular configuration with the (possibly variable) acoustics of the hall forms the characteristics of what can be understood as an instrument to be composed for. Getting to know this instrument is essential and composing for it becomes a site-specific practice.

StiffNeck has been developed specifically to support such processes, allowing to perform parts of the site-specific compositional work off-site by means of auralisation based on room impulse response measurements. Besides its function as a tool to compose for real acoustic spaces, StiffNeck lends itself equally well to create virtual acoustic spaces by combining and modifying room impulse responses. The application features efficient handling of very large sets of measurements and flexible switching between loudspeaker configurations, microphone sets and listening positions for an easy comparison. StiffNeck acts as a transparent reproduction backend: the same channel layout can be used as for working in the hall, allowing for a seamless transition between work on and off site. Beyond the acoustic representation of a particular loudspeaker configuration in a specific hall for several listening positions, StiffNeck provides for a geometric representation of the loudspeakers, listening positions, and the hall. This allows compositional processes as well as sound synthesis and rendering to take into account the locations and orientations of the loudspeakers in relation to the geometry of the hall. Furthermore, selective modifications of impulse responses can be performed based on the geometric relationship of loudspeakers and measurement microphones.

This paper will describe the compositional approaches (section 2) that motivated the development of StiffNeck, the technical aspects of its development, such as the room impulse response measurements (section 3) and the implementation of the auralisation tools (section 4), followed by an evaluation of the application (section 5).

2. IN SITU COMPOSITION

In the context of the research project The Choreography of Sound [1] a particular approach towards electroacoustic composition called *In Situ Composition* (ISC) has been in-

investigated and developed further. Typical for this approach is that large parts of the compositional process take place at the venue where the work is going to be performed or presented. ISC aims at exploring the distinctive features of particular loudspeaker configurations, usually involving many and diverse units in unusual arrangements. Most often designing the loudspeaker configuration is itself part of the compositional process. Empirically exploring the interactions of loudspeakers, sound material, spatialisation algorithms, listening positions and the acoustics of the hall is a central component of the ISC approach. In this way site-specific works are created, sharing the features of compositions and installations while aiming at taking maximum advantage of a particular setup.

ISC is related to acousmatic practices using loudspeaker orchestras to perform pieces by distributing a relatively small number of source channels (classically 2, but also 4, 8, or more) to a large number of loudspeakers arranged according to traditional principles and the acoustics of the hall. Taking artistic decisions based on the concrete listening experience in the hall, involving rehearsals and in-depth engagement with a particular setup is typical for both acousmatic music performance and ISC. The difference being that the former is a performative and interpretational process, which will only concern certain aspects of a work. With the latter, all options offered by (and constraints inherent to) a setup can still be made productive for the compositional project. In ISC the way the sound is choreographed is understood as an integral component of composition and composition is thought as a practice always in touch with its final result through listening.

Most approaches towards sound spatialisation in electroacoustic music aim at creating reproducible conditions for the projection of a piece in different concert halls and using different loudspeaker configurations. The implicit ideal is to provide all listeners across all halls with the most similar experience possible. As a site-specific approach, ISC welcomes the idiosyncrasies of a venue and makes them part of the work. Furthermore it assumes that listeners will possibly make quite different experiences of a work, especially if they are free to choose and change their listening position. This also implies that a transposition of a thus composed piece to another venue will most probably require big parts of it to be recomposed, i. e., creating another site-specific version of it. If such a transposition, in case it is desired at all, is feasible from an artistic point of view will depend largely on the work and the differences between the venues.

As this brief characterisation of ISC and its relations to other practices show, composing that way requires a particular production situation. First and foremost there is the need for an extended access to the venue with the possibility to experiment extensively with loudspeaker configurations and listening positions. As it will most probably be unrealistic to compose a piece in one session, recurring access to the hall will be important with periods of off-site work in between. The latter are important in order to gain spatial, temporal, acoustic, perceptual, and conceptual distance from the very demanding work in situ. During these

periods it is necessary to be able to work with different kinds of models of the site, also allowing for gaining distance through the abstractions inherent to models. Typical models will be visual, geometric, or acoustic – including combinations of those.

StiffNeck is a tool combining exactly these three types of models in an integrated environment. The navigable 2-D and 3-D visualisations of the hall, loudspeakers and listening positions are based on their geometric representations. These are also accessible numerically and can be used to perform computations in 3-D space in order to inform sound synthesis and projection. Auralisation based on measured room impulse responses allows to gain different acoustic perspectives on a loudspeaker configuration and its interactions with the hall. These are available in various head-related and other formats.

In the context of ISC, StiffNeck has proven to be a very productive and reliable tool. On site work can be prepared thoroughly and the compositional process can continue off-site, taking full advantage of the listening experiences gained in the real space. It has been found that auralisation works particularly well if the listener has been exposed to the real space before. Then the memory of the in situ experience seems to complement the auralisation best. In addition to providing a real alternative to working in situ, StiffNeck can be used to create stereo or surround versions of multi-channel works and capture at least some aspects of the particular acoustics they have been composed for. For this task StiffNeck's impulse response modification features (especially to reduce reverb time) are very important. But not only ISC approaches can benefit from auralisation. Also acousmatic performances can be prepared and rehearsed and the rendering of pieces using traditional spatialisation approaches can be tested and optimised using StiffNeck. Furthermore, the vast number of room impulse responses available for StiffNeck make it also a very interesting tool to create artificial acoustics. By combining speaker and listening positions from different rooms, a wide range of surreal spaces can be created at ease.

The type of auralisation used in StiffNeck allows for modelling the room acoustics only for static listening positions. Effects due to smaller or larger head movements are not represented. This can be considered a disadvantage when compared to the in situ listening conditions. But from a compositional point of view this freezing of the head movement (as if the listener suffered from a stiff neck), offers a very interesting opportunity to engage in depth with this condition, to use the constraint of the locked ears to explore an acoustic dimension unaccessible in situ.

3. MEASUREMENTS

As mentioned above, StiffNeck provides auralisation based on measured room impulse responses. As the tool's development is closely connected to our main laboratory, KUG's *György Ligeti Hall*, the most extensive set of impulse responses for use with StiffNeck has been measured in this very space.

During the development process, a standard microphone



Figure 1. Motorised speaker rig and measurement setup at *György Ligeti Hall* at KUG Graz.

array configuration emerged, which should allow for several auditive perspectives on the space using headphones or loudspeakers. The array consists of a Brüel & Kjær dummy head with additional DPA 4060 miniature microphones located on its temples, a Schoeps spherical microphone, a Soundfield first-order Ambisonics microphone, two omnidirectional Schoeps MK 2 H in a large AB setup and a monaural reference.

The measurements were carried out using free software exclusively, mainly an extended version of *Aliki* by Fons Adriænsen [2], which implements the swept sine measurement method developed by Angelo Farina [3]. In order to gain a high signal to noise ratio, we used a logarithmic sweep of more than ten seconds length. The high number of channels and iterations required a largely automatic measurement procedure, which has been achieved by custom extensions to *Aliki* and further tools. These extensions are described in more detail in [4].

In the beginning of *StiffNeck*'s development, the microphone positions and loudspeaker configurations were chosen for measurement to support virtual *in situ composition* of specific pieces. After successful applications of these first measured sets, the goal shifted towards a complete matrix (i. e., all combinations) of several microphone positions and loudspeaker setups. Although some of the combinations may be less useful than others, the orthogonal access to the impulse responses provides a more universal and aesthetically more open access for explorations and comparisons.

Currently, we provide a complete matrix of five loudspeaker configurations (using the 33 motorised speakers) plus 74 fixed speakers and subwoofers, each measured at ten microphone positions using the abovementioned multichannel array. Additionally, there are four measurement

positions using a modified microphone array positioned at the floor with the dummy head laying on its back. Further measurements include configurations using additional speakers such as IEM's icosahedral array [5], which are more or less specific to certain composed pieces but may still find interesting use cases.

The impulse response sets for use with *StiffNeck* or other software is being made available online (cf. section 6). Several subsets are bundled for different practical applications. The filenames follow a certain nomenclature, which is compatible with *StiffNeck*.

Previous measurements from other spaces will be published at the same place, namely impulse responses from SARC's Sonic Lab, IEM's Cube and other locations. While *StiffNeck* can use them for auralisation with little modifications, the full functionality may be achieved only after additional adaptations. Constructing geometric or visual models from these spaces would require the incorporation of exact geometric metadata that is currently not provided, while a three-dimensional representation would have to be modelled for an entirely navigable 3-D visualisation.

4. IMPLEMENTATION AND FEATURES

StiffNeck is implemented using the SuperCollider sound programming framework and requires a few additional external programmes for certain tasks. It is available as a library module for SuperCollider (a so-called *Quark*) as well as a standalone application.

StiffNeck combines a library for the geometric representation of objects (*Gr*), extensive databases of configuration data for KUG's *György Ligeti Hall* including an import facility of motorised speaker control configurations, the convolution based auralisation engine, and a graphical user interface for selecting and modifying impulse responses and

visualisation facilities.

StiffNeck exposes its inputs and outputs as ports to the Jack audio server. Thus any Jack-aware application can be connected in order to auralise its output using the selected impulse response set.

4.1 Convolution Based Auralisation

For performing the actual convolution, StiffNeck uses Fons Adriaensen's realtime convolution engine *Jconvolver* [6], which has been compiled for more than the 64 default input channels. *Jconvolver* is multithreaded and highly efficient, which allows for handling large numbers of impulse responses, each with a length of several seconds. It is configured using a configuration file describing an arbitrary static convolution matrix.

In StiffNeck, a configuration file is generated depending on the impulse response sets selected for auralisation, then *Jconvolver* is run in the background. On a settings change, a new configuration file is generated and the convolver is restarted. This leads to a short pause in the auralisation output rather than a smooth transition, which turned out to be fine for the purposes described. However, optimisations are planned for a closer integration of *Jconvolver*, e. g. including a direct transfer of the configuration via shared memory or OSC and a dynamic exchange of spectral impulse response data at runtime.

4.2 Impulse Response Modification

StiffNeck allows for a few basic modifications to the impulse responses. The overall length of the response files may be reduced by prematurely fading out, which limits the maximum reverb time of the auralisation but significantly saves processing power, especially with a high number of channels.

A second, independent parameter allows for windowing the reverb tail of the original impulse response with another exponential decay in order to simulate a shorter reverb time, i. e., a drier space. This experimental feature is motivated by the observation that especially auralisation on loudspeakers often suffers from more apparent reverb than the remembered on site impression.

Modified impulse response sets are processed in SuperCollider and stored in a cache location from which they are loaded by the convolver. A more efficient and elegant way of exchanging modified impulse response data with the convolution engine is planned for a future version of StiffNeck.

4.3 Visualisation

StiffNeck includes several means of visualising geometric constellations of loudspeakers and listening positions, other (e. g. compositional) objects and the boundaries of the space. From the internal numerical representation, different visualisation backends may be fed.

A 2-D visual interface is implemented using builtin SuperCollider GUI facilities. For a fully navigable 3-D model of the *György Ligeti Hall*, the external renderer *Blender* may be controlled via an extensible OSC interface.

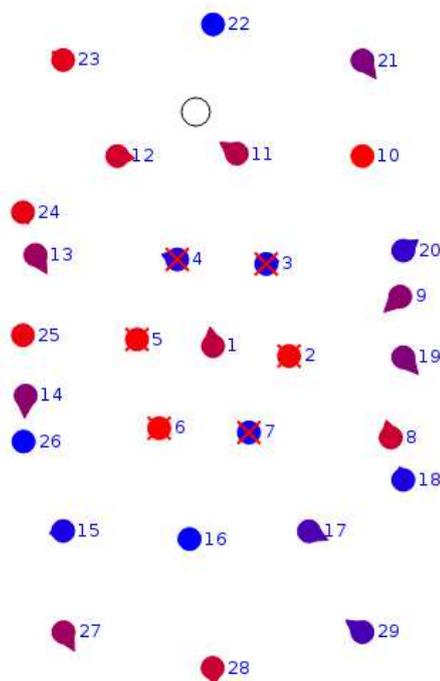


Figure 2. Two-dimensional visualisation of 29 motorised speakers in *György Ligeti Hall* (open circle represents listening position).

5. EVALUATION

Several development versions of StiffNeck have been evaluated informally, as it is common for tools in an artistic research context. This also happened in order to gain insights for its further development.

As part of a software presentation during the event *On the Choreography of Sound* in September 2012, the audience was invited to a direct on site comparison of the real and the auralised *György Ligeti Hall*. Headphones were placed at two positions in the space which have been used as microphone positions for measurements. The real loudspeaker configuration was the same as the measured one. Using a switch in the headphones, the sound projection of an algorithmically controlled, spatial realtime pattern was toggled between the real loudspeakers in the hall and the auralisation via binaural convolution and headphone projection. It turned out that for the person who put on and off the headphone and thus issued the switch between the two projection methods, the difference was not evident at all as the perceived auditive scene did not seem to have changed. Only the rest of the audience with no or with “slave” headphones noticed the interruption of the speaker projection.

For the artistic research symposium *Mind the Gap*, carried out in *György Ligeti Hall* in March 2013, six artists were invited to compose pieces for a specific loudspeaker setup for which impulse response measurements have been carried out. The artists were provided with a reduced development version of StiffNeck, enabling them to auralise and to visualise the mentioned speaker setup. Additionally, a technical briefing on the symposium website [7] intro-

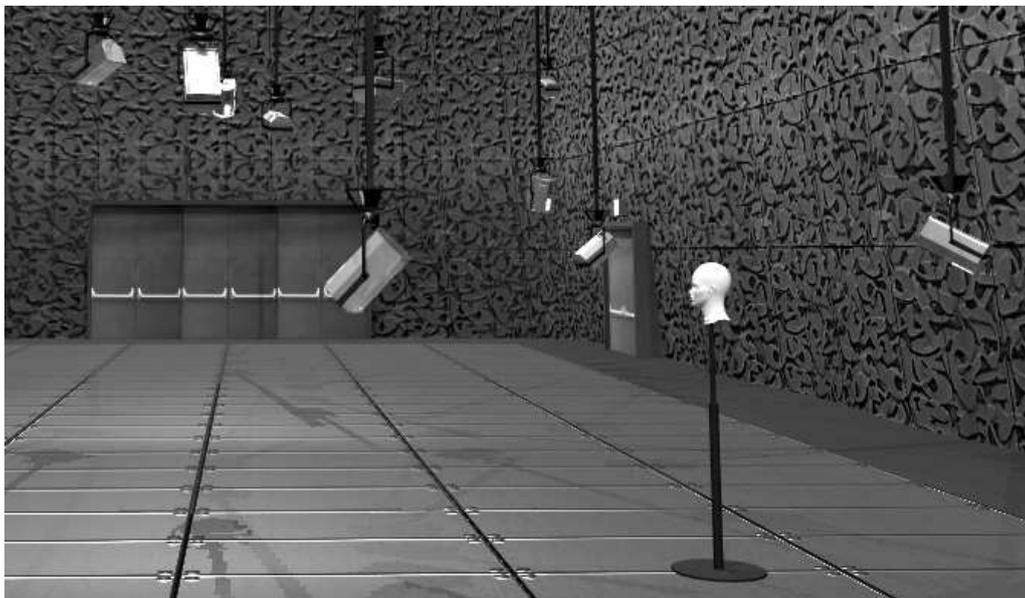


Figure 3. Three-dimensional visualisation of motorised speakers and dummy head.

duced the hall, the speaker system, the channel layout and the provided auralisation technique. The technical briefing itself has been produced using the same auralisation application.

Some of the artists made excessive use of the provided auralisation tool in order to prepare their contributions for the symposium. We received very positive feedback on the usability of the software and the validity of the approach. This feedback referred to both the cases of composing a new piece for the space in situ and adapting an existing multichannel piece for performance in *György Ligeti Hall*.

6. AVAILABILITY

StiffNeck and various sets of impulse responses are being made publicly available at the impulse response database site of IEM, <http://irdb.kug.ac.at>.

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