AWESOME - A TOOL FOR SIMULATING SOUND ENVIRONMENTS

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ABSTRACT

Sounds are (almost) always heard and perceived as parts of greater contexts. How we hear a sound depends on things like other sounds present, acoustic properties of the place where the sound is heard, the distance and direction to the sound source etc. Moreover, if the sound bear any meaning to us or not and what the meaning is, if any, depends largely on the listener's interpretation of the sound, based on memories, previous experiences etc.

When working with the design of sounds for all sorts of applications, it is crucial to not only evaluate the sound isolated in the design environment, but to also test the sound in possible greater contexts where it will be used and heard. One way to do this is to sonically simulate one or more environments and use these simulations as contexts to test designed sounds against.

In this paper we report on a project in which we have developed a system for simulating the sounding dimension of physical environments. The system consists of a software application, a 5.1 surround sound system and a set of guidelines and methods for use. We also report on a first test of the system and the results from this test.

1. INTRODUCTION

Human auditory perception has a remarkable and sophisticated ability to identify sounds [1, 2]. Articles in the field of sound design includes a wide range of topics, such as aesthetics, cognition, intuition, design patterns, sound classification etc. [3, 4]. Based on this it can be argued that sound design is an inherently complex task that demands skills in a host of different areas and fields of competence. As a designer of sound for auditory displays of various types you need to have at least basic understanding of things as seemingly disparate as auditory perception, aesthetics of sound and music, acoustics and psychoacoustics together with experience in using digital media editing software and hardware. The field is complex, a large number of competencies are involved in even moderate design efforts and there are vast numbers of possible applications ranging from the design of sounds for kitchen appliances via car blinkers to mobile phones and software for personal computers. Together this suggests there be a large number of easy-to-use, yet powerful professional tools and methods available to support the designers in their roles as creators of sounds that users are, in many cases, likely to hear many times every day. Unfortunately these tools are still, to a large degree, yet to be created.

Auditory perception is based on what is sometimes described as two streams, one in each ear [4, 5]. Our auditory perception is also to a large degree associative, individual and a matter of taste [6]. When designing auditory displays it is therefore important to test different solutions with different groups of potential users to secure the design. Also, when designing sounds that are to be played and heard together with other sounds in a larger auditory context, it becomes important to be able to test the designed sounds in that context or at least in a trustworthy simulation of it [7]. If a sound can not be heard over the background noise, it does not matter how well designed it is.

When designing the individual sounds for auditory displays of various types, there are tools available in the form of recording equipment, sound synthesizing, sound editing systems etc. Often these systems have their origins among artists and in the music industry or in radio and TV broadcasting. There is also an emerging and growing set of design methods available influenced and inspired by theater, film, industrial design and game development just to name a few [8, 9]. Still, there are plenty of research and development to be done to be able to compare what is available in the field of sound design to what is available in, for example, the graphical field. Then again, when it comes to testing the designed individual sounds in their larger context for effects such as masking, repetition and position in space, the tools are largely missing.

Visual artists and designers have always been sketching and graphic designers have a large palette of tools available for trying out and testing ideas. Lately, with the ability to easily record sound and with the advent of computers and music synthesizers, also musicians have been able to sketch and test musical ideas, from small fragments to large orchestral pieces. But for the industrial designer working with the design of sounds as part of a solution, the situation is radically different. There are very few, if any, systems available from the shelf that can be used, without great investments in training, equipment etc. to sketch out a whole soundscape and to test ideas and solutions. The systems available today are most often created for other purposes, such as music creation and editing or for general sound editing. From a more general designers perspective, these systems demand of the designer to put great efforts in learning the systems in order to be productive. One can suspect that often, these learning efforts are not perceived as corresponding to the benefits of the outcomes.

The tools available today for general sound design can broadly be put into the following categories:
- Tools for music production and DJ'ing, etc.
    - Cubase [10]
    - Logic [11]

- o Ableton Live [12]
- o Traktor Pro [13]
- General tools for audio editing, etc.
  - o Audacity [14]
  - o Pro Tools [15]
- Software for sound syntesis, etc.
  - o Native Instrument's Reactor [16]
  - o SuperCollider [17]
  - o Max MSP [18]

The products listed above are all very competent with immense possibilities to create, edit, apply DSP effects, mix, etc. sound for numerous situations and contexts. Here, the problem is that these relatively large software systems, with few exceptions, are designed for audio professionals. The functionality of most of them can be greatly expanded by the use of various types of plug-ins and there is an ever-growing number of plug-ins for room simulation, sample libraries, software instruments and sound effects. For the experienced and professional users these softwares mean tremendous opportunities to perform all sorts of sound design tasks. The problem we want to highlight here is that the systems are very demanding and requires special training and long-time experience in order to be productive. As sound and audition are becoming more and more important in the design of today's products and services, it is an increasing problem that the tools for sound design are to a large degree inaccessible to the general, non-expert audience. One special problem sound designers are faced with is to sketch out and evaluate sound design ideas as parts of greater wholes, to be able to judge if a designed sound will work as intended together with other sounds in the target environment.

This paper describes a system that aims at being accessible and useable also for non-expert users, enabling designers without special audio training or experience to sketch, try and evaluate sounding ideas.

Figure 1. A typical Awesome workstation including computer, audio interface and 5.1 surround sound system.

2. AWESOME – AUDIO WORK ENVIRONMENT SIMULATION MACHINE

AWESOME is a system used for sketching and testing sound design solutions in simulated sound environments (figure 1). The environments are simulated as 2D-spaces and sonically rendered through a standard 5.1 surround sound system. Using the Awesome system you can build sounding replicas of target environments, import designed sounds as audio files to these replicas, position the sounds in 2D-space and move the system's listener object's position and orientation in the environment. In this way the sound design can be evaluated and tested with respect to the overall target environment in which the designed sound or sounds are to be used. This in turn can be used for decision making, to demonstrate ideas and to test design solutions. In focus when designing the system has been a user with only basic knowledge in and experience of traditional sound production equipment. Emphasis has been put on embedding knowledge about general sound design issues into the system in order to make it accessible to users without specialized training and knowledge in more traditional sound design tools. The aim is to create a system that empowers users in a wide range of professional and training situations with a need for sketching and testing sounding ideas.

Traditionally, audio and music editing softwares have emphasized sounds timely dimension. Often these systems are based around timelines that allow the user to organize layers of sound in time. The Awesome system also has a timeline and gives the users similar basic functionality to organize layers of sound in time. But in addition, the system also gives the users functionality to organize sounds in simulated, virtual spaces and to move a listening avatar around in these spaces. In this way, not only the timely aspect of sound but also the space aspect are opened up and can be modeled and worked with.
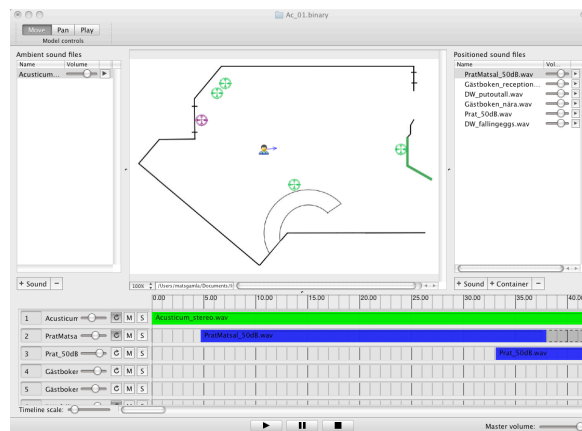

Figure 2. The Awesome main project window.

2.1. The AWESOME system

The total Awesome system consists of five major parts:
- A Mac OSX-based software application.
- A multi-channel audio interface.
- A 5.1 surround sound loudspeaker system.
- A sound library with a set of audio files for a number of typical use-scenarios.

- A set of recommendations, methods and guidelines. The recommendations regard the choice of equipment, for example the surround sound system, audio interface and recording equipment. The set of methods and guidelines includes basic instructions for recording techniques using the recommended equipment, instructions for calibrating the sound system and a general methodology for using the system for a number of typical use-scenarios.

The Awesome software application is built around projects. An Awesome project consists of the following three parts (figure 2):

- The sound library in which the audio files used for the sonic simulation are organized. The library is divided in two parts (figure 3). One part for point sound sources with distinct location in the rendered 2D-soundspace and one part for non-positioned, ambient sounds.
- The graphical model of the simulated environment. The model is represented by a two-dimensional top-view image of the environment (figure 4). One example of a typical model is the blue print of a room or the picture of a car from above. In the model view, sound sources are positioned, animated and moved in 2D space. The model also contains the single listener object that can be moved and rotated within the model and in relation to the individual sound sources.
- The timeline. Sound sources can be positioned in time on the timeline, that is, given a start-time and duration (figure 5). The timeline can be played back creating a pre-defined sequence of sound events.

Figure 2 shows the software application's main window with the model view in the centre surrounded by the ambient and the positioned audio file libraries and with the timeline below. The system itself does not synthesize any sounds, instead all sounds used to construct the simulated sound environment are imported to an Awesome project as standard audio files in WAV, AIFF or MP3 format. The resulting soundscapes are rendered through the standard 5.1 surround sound system.

2.2. The audio file library

The audio file library is divided into two parts, one part for ambient, non-positioned sounds and one part for positioned sound objects. Examples of ambient, non-positioned sounds are background sounds such as wind, sounds from ventilation or the sounds from airspeed and tires on asphalt in a car. Examples of positioned sound objects are a bird singing, a human voice, the hum from a refrigerator or the ticking from the blinker relay in a car. In the library, the basic volume of each sound file can be adjusted in order to balance the sounds relative volumes. Each audio file in the library can also be individually played directly from the library window as a complement to playing it from the model and the timeline. (See figure 3.)

The positioned sound sources must be mono audio files. A sound source is positioned in the model by dragging it from the library and dropping it on the model. Once positioned in the model, the playback of the sound object will have a rendered position in the surround sound system relative to the listener object's position and orientation (rotation).

The positioned sound files in the library can be collected in "containers" for easy comparison between files. Only one audio file in a container is active at a time. Containers can be dragged from the library to the model just as single audio files, but only the active audio file in the container will be played as the container is triggered.

Figure 3. The ambient and positioned audio file libraries. Note that each audio file has its own volume control and Play-button.

The ambient sound sources can be either mono or multi-channel audio files. The user can assign the channels of a sound file to channels in the rendering 5.1-surround sound system. A stereo-file can for example be assigned to the channels of the surround sound system so that the left channel of the stereo file is routed to both the front left and the rear left speakers of the surround sound system and the right channel of the stereo file is routed both to the front right and rear right speakers.

2.3. The model view

The centre of the Awesome system is the "model view" (figure 4) where the positioned sound objects are organized in space. The model view also contains the single listener object that can be moved and rotated in relation to the model and the positioned sound objects. The base for the model view is a two-dimensional top-view image of the environment to simulate. The scale of the model view can be set. When a positioned sound object is moved in the model view, the change in position is reflected in the sounds position in the soundscape, rendered through the surround sound system. The same is true when the listener object is either moved or rotated in the model view. The ambient sounds do not have positions and are therefore not affected by the listener object being moved or rotated.

Positioned sounds are placed in the model view by dragging them from the audio file library and dropping them on the model view. Once in the model view, the sound objects can be moved and re-positioned as appropriate. Sound objects can also be animated by assigning an end position relative to the start position. When triggered, the sound's position in the surround sound system will pan from the start position to the end position during the duration of the sound.

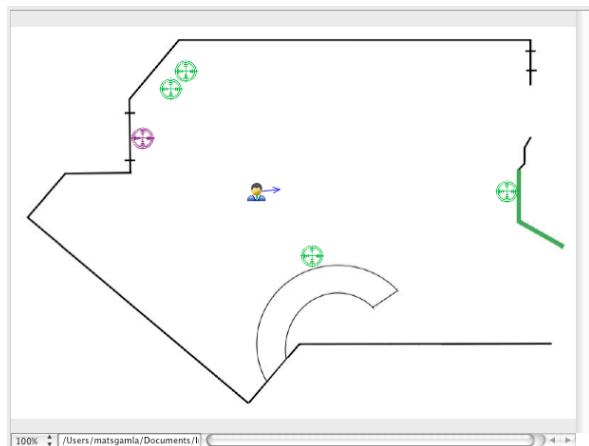Individual sound objects can be triggered from the model view by clicking the sound object's symbol.

Figure 4. The model view. The arrow on the listener object denotes the direction of the listener in the environment.

2.4. The timeline

Sound objects can be placed on the systems timeline (figure 5) and triggered in sequence as the timeline is played. The timeline consists of a time ruler and a number of "tracks". Each track corresponds either to an entry in the ambient sound library or to a positioned sound object placed in the model. Ambient sounds are placed on the timeline by dragging an object from the library and dropping it on the timeline. Positioned sound objects are placed on the timeline by dragging them from the model view and dropping them on the timeline. Individual tracks can be muted, solo'ed or looped on the timeline. Each track also has a volume control for further adjustment of the volume.

Markers can be placed on the timeline and the current position can be moved to a marker by activating a corresponding key on the keyboard. The timeline region between two markers can also be looped.
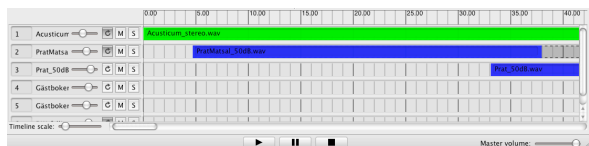

Figure 5. The timeline.

2.5. Built-in acoustics simulation functionality

In the model view, the listener object can be moved and rotated in order to simulate listening from different positions in the real environment. To create an as realistic simulation as possible, given the technical constraints and limitations of the system, two global room characteristic properties can be set on a per-project basis.

- The rolloff-factor. This factor controls how much a positioned sound is attenuated as a function of the distance to the listener object. This factor depends on the scale of the model view and the acoustic characteristics of the simulated environment.

- The reverberation of the room. The system contains a simple yet effective reverberation unit. For each sound object, the balance between the signal affected by the reverb unit ("wet signal") and the unaffected ("dry") signal is modulated as a function of the distance between the positioned sound object and the listener object. In a real acoustic environment, the influence of reflections of a sound from walls and other surfaces increases as the distance between the listener and a sound source increases. The Awesome application mimics this effect so that the amount of reverb (wet signal) increases and the amount of direct (dry) signal decreases when the listener object's distance to a positioned sound source increases.

The relative volumes of the sound sources (audio files) can be adjusted in order to create a realistic balance between the individual sounds comprising the total simulated sound environment.

2.6. Surround Sound System

There are of course several optional methods to arrange the sound playback functionality. The two main options are loudspeakers or headphones. So far we have used a 5.1 mid-range surround sound loudspeaker system exclusively. The system consists of 5 M-Audio Studiophile AV 40 speakers [19] and a M-Audio SBX10 subwoofer [20]. The following motivates the choice of playback solution:

- Loudness. To be able to establish a level of loudness in the simulations with a perceived correspondance to the loudness in the real environment, we want to be able to measure the sound pressure level with a dB-meter. This is not possible when using headphones, which leaves us with the loudspeaker option.

- Collaboration. The aim is to create a system that can be used by groups to collaborate on sound design issues and decision-making. We believe this is easier done with a loudspeaker system rather than with headphones.

- Realism. The psycho-acoustic models available to us does not make it possible to render sound positions using headphones in such a way that "from the front" and "from the rear" are clearly distinguishable. Using a loudspeaker surround sound system this rendering works better, adding to the total realism.

In addition to this we also wanted to keep the cost for the loudspeaker system at a moderate level in order to make the system as accessible as possible for the target groups. The loudspeaker system used and recommended is therefore a mid-range price system.

2.7. Methodology

The intended use of the Awesome system is to sketch, test and evaluate sound design solutions when designing technical systems of various types. A typical Awesome use case scenario can be divided into the following three main parts:

1. Designing, recording and/or synthesizing sounds for both the system under development and other, typical sounds in that systems target environment. These sounds are stored in standard audio files and are used in the following steps

to build the simulated sound environment. Note that Awesome is not intended for this part. Instead traditional recording, synthesizing and editing tools are used.

2. A new Awesome project is created and the audio files from the previous step are imported into this new project. The sounds for the system under development and the sounds for the environment surrounding this system is positioned in the project model view, relative volumes are adjusted, the simulated environments basic acoustic parameters are set in the project and the total soundscape is simulated as closely as possible, given the skill level of the user and the technical constraints of the Awesome system.

3. The sounds for the system under development are tested and evaluated in the context of the total soundscape simulation. Different design solutions can be compared, decisions made and the most appropriate solution selected.

Note that the Awesome system is not intended for the basic design of sounds and the creation of the corresponding audio files in the first part above. Instead the system is used for parts two and three to create the experience and simulation of the whole soundscape including both the designed sounds and sounds of the environment in which they are going to be used.

The development of the Awesome software application is paralleled with the development of a methodology to help and support users to recreate and simulate the sounding aspects of physical environments as realistic as possible.

3. VERIFYING TEST

A first test to verify the system has been conducted. Six test subjects were asked to use the system to recreate the sounding dimension of two physical environments, the interior of a car and the reception of an office building. In focus for this test were the test subjects subjectively perceived experiences of the two environments and how well the Awesome system let them recreate this experience. It should be noted that this time, we were not interested in an objectively measured similarity between the real environment and the replica simulated by the system, but instead the subjectively perceived similarities and differences.

Prior to the test, a number of characteristic sounds in each of the two environments were identified and recorded by the test leaders. In the tests, these recordings were then used by the test subjects as building blocks when recreating the experienced soundscapes of the two environments.

Figure 6. The interior of the car used for tests.

The first environment was the interior of a car driving with the speed of 70 km/h. Apart from the ambient noise from tires, wind, motor and power transmission, the sounds from the horn, the blinker relay, the wipers and the radio were simulated. The second simulated environment was the reception of an office building with people talking, telephones ringing, the sounds from the entrance to the in-house restaurant and the sounds from two interactive applications. The test subjects where sound engineer, music composition and studio musician students at the Department of Music and Media, Luleå Technical University in Piteå, Sweden. Unfortunately only male students volunteered for the test sessions.

Figure 7. The reception used in the tests.

Each test sessions was divided in two parts, one for each environment to simulate. Each simulation sessions was also divided into two parts. First, one of the target environments was experienced firsthand. The test leader and the test subject visited the environment (car and reception respectively) and listened to the predefined characteristic sound sources and the overall ambience of the environment. The test subjects were asked to pay special attention to and try to memorize the following aspects of the environments.

• The overall loudness of the environment.
• The loudness of the individual sound sources relative to the whole.
• How the experience of the sounds depend on the test subjects position and orientation in the environment.
• The positions of the sounds in the environment.

Immediately following this firsthand experience, the test subjects were put in front of the Awesome software application with the task to simulate the soundscape of the environment as close as possible based on the experience and memories from the firsthand experience. In half of the test sessions, the car-case was done first followed by the reception case and the reception was done first and the car last in the rest of the sessions.

Working with the simulations was documented in writing by the test leader and followed the same basic structure in both cases.

1. The test persons where presented an Awesome project with a library of pre-imported audio files recorded in the actual environment as a start. The library contained one ambient

audio file and a number of audio files for positioned sound sources. The project also had a model of the environment set up with basic settings. No sounds had been added to the model view or to the timeline prior to the test sessions and nothing else in the project file was pre-set or manipulated in advance.

2. In order to establish a basic sound pressure level the test subjects were instructed to start with one of the audio files and adjust the volume of that sound so the perceived loudness of the simulation matched the memory of the loudness in the real environment. At this point no equipment for measuring the sound pressure was used, the sound volume adjustment was based solely on the test subject's memory of the perceived loudness.

3. The sound pressure of the simulated ambient sound was measured using a dB-meter. The test leader recorded the result in writing.

4. Next, the positioned sound sources were placed in the model view. The volumes of the audio files were adjusted to match the loudness of the sound in the real environment as perceived and remembered by the test subject.

5. The acoustic characteristics of the simulation were adjusted to match the characteristics of the real environment as close as possible, given the technical limitations of the system.

6. A small questionnaire with seven statements with accompanying seven grade Likert-scales was filled out. The test subjects were asked to relate to what extent experiences of the simulations made with the Awesome system corresponded to the experiences of the real environments. The aspects asked for were: the total loudness of the environments; the loudness of the individual sound sources in relation to the whole soundscape; the acoustics of the environments; self-movement and the experience of listening from different positions in the environment; aspects of simulating sequences of sounds and finally the total experience of the simulation compared to the real environment.

The same structure was then repeated for the second simulation session. The test subjects were not given any restrictions in time to complete the simulations, but were instructed to take the time needed. The subjects worked with each simulation between 10 and 15 minutes to be satisfied and the simulation considered to be as close to the original as the system allowed. Finally, a small, semi-structured interview with the test subject was carried out led by the test leader. In this interview, the test subjects were given the opportunity to express complementary thoughts and ideas not covered by the more formal questionnaire.

Due to a blizzard on one of the days for the test sessions, the sessions for three of the subjects had to follow a slightly different route than initially planned. The blizzard made driving the car impossible, therefore these three test subjects did the reception case on one day and then came back two days later to do the car case. This was not deemed to affect the test and the results negatively.

4. RESULTS

On an overall level, the results show that the Awesome system is already in this stage working relatively well, allowing

relatively trustworthy simulations of the two rather different environments used in the test. In the questionnaires, the test subjects were asked to rate how well the experience of the simulation as a whole corresponded to the experience of the real environment. For the car-case one subject rated the similarity 7 on the seven-grade Likert scale, three subjects rated it 5 and two rated it 4, resulting in a mean value of 5.0. In the reception case, four subjects rated the overall similarity between the simulated and the real environment 5 on the seven-grade Likert-scale and two rated it 4, resulting in a mean value of 4.7. In the interviews, a majority of the subjects expressed the opinion that the quality of the simulations was better than expected and that the similarity between the simulated and the real environments was also better than expected. This is especially true in the smaller and more restricted car-case.

Two weak aspects of the system were identified. The first is the simulation of room acoustics and reverberation. The second is related to sound pressure, loudness, frequency response and the general sound quality of the system used to finally render the soundscape. To create a sense of acoustics and reverberation, the built-in reverb unit of the OpenAL implementation in Mac OS X was used. The car-case did not present a problem in this aspect, since no reverb or other acoustic simulation was considered necessary to simulate the acoustically limited and dry car environment. Instead the acoustics built in the recordings made in the car was in this case sufficient. In the reception-case on the other hand, the situation was different. The reception is a relatively large room with stone floor, several glass walls and an irregular shape, which together creates special acoustic conditions. Using the technology available it was only possible to partly mimic the acoustic experience of the reception. In the interview, the test subjects pointed out the following aspects that presented problems when working with the simulation:

• The simulated reverberation was deemed harder and more metallic than the softer, more diffused reverberation of the real room. Having access to a more advanced reverb unit would increase the realism of the simulation.

• Several of the test subjects reported problems finding settings that made it possible to simulate listening to a sound source both close up and at a distance in a way that corresponded to the experience in the real environment. Once again, a technically more advanced reverb unit together with more developed algorithms for filtering and attenuation of sound sources as functions of distance to the virtual listener are needed.

In the first phase of each simulation session, the test subjects were asked to establish a basic loudness level based only on their ears and memory of experienced sound pressure in the environment to simulate. When these basic loudness levels were established, it was measured using a dB-meter. The results show differences between the two cases. In the car-case, the ambient sound of the car interior was used. In the reception case the ambient was too quite to effectively use for this purpose and instead the recording of a conversation between two persons were used to establish the basic loudness level. It turned our that in the car-case, the experienced and measured levels differed significantly. Measurements of the sound pressure in the simulations showed that, when using only ear and memory, all test subjects adjusted the loudness level to

between 5 and 10 dB lower than the level measured in the real environment. In the reception-case, when adjusting the loudness level of the conversation, the measured level did not differ more than a few dB up or down.

5. DISCUSSION

In this paper we have reported on a system that can be used to create simulations of the sounding dimension of physical environments. The system consists of a software application, a 5.1 surround sound system and a set of guidelines and methods for use. We have also reported on a first test of the system and the results from this test.

Our aim has been to create an audio work environment with the space-time dimension in focus. Awesome differs from most other digital audio workstations (DAW's) and sound editing systems in one important aspect. In the Awesome-system the listener object can freely be moved and oriented with respect to the simulated environment and the sound sources in it. Traditional systems for editing surround sound, such as Cubase, Logic and Soundtrack Pro [21] are built on a metaphor where the listener is always statically in the center of the environment and cannot be moved in relation to it. Instead, to simulate the listener moving, each sound source must be moved individually. In these traditional systems it is therefore very difficult to make scenarios where the listener is moving relative to the sound sources in real-time. Most often you end up with a couple of audio snapshots or frozen "still lifes" of possible sound scenarios. The Awesome system makes it possible to create more dynamic scenarios and simulations of environments and the listeners relation to them.

Larsson et al. argues that "[o]ne can think about three different levels of technological sophistication when building mixed or virtual auditory environments – physical, perceptual, and cognitive" [22]. On the physical level, this means that high sophistication in the rendered sound scenes means a close approach to the physical sound properties of the real environment, the sound from the loudspeakers sounds more or less exactly as the original sound source. On the perceptual level, Larsson et al. notes that today's knowledge in auditory perception allows for technical simplifications, and gives as example audio coding schemes (i.e. MP3 compression) and reduced temporal and spatial quality of recorded impulse responses. This means that some technical sophistication can be sacrificed if it can be assumed that the listener will not perceive a sound or part of a sound. Larsson et al. also points out the recent notion of ecological psychoacoustics and the importance of cognition when creating auditory scenes. We know that the sound of airplanes usually comes from above, this knowledge tends to steer our perception, so the sound of an airplane is perceived to come from above even though the sound is presented to the listener at their head level. Also in this case some level of technical sophistication can be sacrificed and replaced with the listener's experiences and knowledge about sounds in the world.

When these ideas are applied on the case presented in this paper, it can be argued that the technique used to render the simulations, not necessarily have to be capable of a one-to-one physical copy of the sounds in real environments in order to give a satisfactory and useful experience. Instead of seeking technical perfection, it becomes important to find a relevant

balance between a number of parameters, that together build the whole experience of the soundscape simulation. When designing the Awesome system, we have focused on the following aspects:

- **Accessible**. The Awesome system is intended to be a cost-effective system based on a Mac OS-computer and a mid-range 5.1 surround sound system. The aim is to create a system affordable to any SME that can benefit from using the system. It must also be possible to place the system in a wide range of locations and rooms, without the need for anechoic chambers etc. and still create useful results.
- **Ease-of-use**. The target user group is non-sound experts with the need to simulate sound environments and to test and evaluate sounding solutions. As such, the aim is to create a system with a relatively low learning threshold and a clear learning path. The aim is also to complement the software system with guidelines and methods for use that support non-expert users and make it possible also for them to create useful results.
- **Embedded knowledge**. Along the same line is the strive for embedding general knowledge about acoustics, psychoacoustics and sound perception in the system. The (non-expert) target users should be able to focus primarily on their design tasks and be relieved from distracting demands from the system.

The project is currently in its first stage of implementation. The first test carried out shows that the system has come some way in all three aspects above. The system does not have to be extremely expensive and it can be placed in an ordinary office or conference room for example and it is still possible to create useful results. The test subjects considered the system easy to use and they were all able to create results they deemed satisfying in short times. The system can and need to embed more general knowledge about acoustics, psychoacoustics and sound perception. A better and more technically advanced reverb unit is needed to be able to more accurately simulate the acoustics of a wider range of environments. Today, the Awesome system does not have any functionality for calibration. Several parts of the total system could benefit from ways and means to more or less automatically calibrate parameters. The test performed revealed the following parameters as highly prioritized: frequency response; overall loudness; sound pressure roll-off; frequency response and the amount of reverb applied as functions of distance to sound sources.

6. FUTURE WORK

The Awesome system has been verified to be a tool capable of recreating, to a certain extent, the sounding experience of two environments. Next steps in the project are to spread the system to a wider audience of users and to have the system used in a wider range of contexts and projects. Anyone interested is hereby invited to use the Awesome system, to comment on it and to suggest improvements and additions.

It is still to be verified that the system can also be used and productive for persons not specialized in audio engineering or audio design. To further strengthen the system in this aspect, the intention is to include also an automatic or semi-automatic calibration module. This module will assist in the basic calibration and balancing of the loudspeaker system used in the

local setup. The calibration module will also assist when establishing the basic loudness and reverberation levels of a project.

The system does not only consist of the software application, but does also include methods and guidelines for the successful simulation of audio environments and the test and evaluation of new sound experiences in these environments. To further develop these methods and guidelines is therefore as important for the future as the development of the software application itself.

7. ACKNOWLEDGEMENTS

8. REFERENCES

[1] A. Nykänen, *Methods for Product Sound Design,* Luleå, Sweden: Luleå University of Technology, 2008.

[2] C. Frauenberger, T. Stockman, "Auditory display design – An investigation of a design pattern approach," *Int. J. Human-Computer Studies*, vol. 67 (2009), pp. 907-922, June 2009.

[3] W.W. Gaver, "What in the World Do We Hear? An Ecological Approach to Auditory Event Perception," *Ecological Psychology,* 5 (1), pp. 1-29, 1993.

[4] P. Polotti, D. Rocchesso, *Sound to Sense, Sense to Sound – A State of the Art in Sound and Music Computing.* Logos Verlag Berlin GmbH, Berlin, Germany, 2008.

[5] C. O'Callaghan, "Auditory Perception," *The Stanford Encyclopedia of Philosophy*, Summer 2009 Edition. Retrieved January 20, 2010 from Stanford Encyclopedia of Philosophy http://plato.stanford.edu/archives/sum2009/entries/perception-auditory/.

[6] J. Fagerlönn, M. Liljedahl, "Tapping into effective emotional responses via a user driven audio design tool," in *Proceedings of Audio Mostly 2009 – a conference on interaction with sound*, Glasgow, UK, 2009, pp. 89-92.

[7] G. W. Coleman, C. Macaulay, A. F. Newell, "Sonic Mapping – Towards Engaging the User in the Design of Sound for Computerized Artifacts," in *Proceedings of NordiCHI 2008: Using Bridges*, Lund Sweden.

[8] V. Alves, L. Roque, "A Proposal of Sound Design Guidelines for User Experience Enrichment," in *Proceedings of Audio Mostly 2009 – a conference on interaction with sound*, Glasgow, UK, 2009, pp. 27-32.

[9] S. Pauletto, D. Hug, S. Barrass, M. Luckhurst, "Integrating Theatrical Strategies into Sonic Interaction Design," in *Proceedings of Audio Mostly 2009 – a conference on interaction with sound*, Glasgow, UK, 2009, pp. 77-82.

[10] Cubase. http://www.steinberg.net/en/products/musicproduction/cubase5_product.html

[11] Logic Studio. http://www.apple.com/logicstudio/

[12] Ableton Live. http://www.ableton.com/

[13] Traktor Pro. http://www.native-instruments.com/#/en/products/dj/traktor-pro/

[14] Audacity. http://audacity.sourceforge.net/

[15] Pro Tools. http://www.digidesign.com/index.cfm?navid=349&langid=100&itemid=33116

[16] Reactor. http://www.native-instruments.com/#/en/products/producer/reaktor-5/

[17] SuperCollider. http://www.audiosynth.com/

[18] Max MSP. http://cycling74.com/products/maxmspjitter/

[19] M-Audio Studiophile AV 40, Destop speaker system, http://www.m-audio.com/products/en_us/StudiophileAV40.html

[20] M-Audio SBX10, http://www.m-audio.com/products/en_us/SBX10.html

[21] Soundtrack Pro. http://www.apple.com/finalcutstudio/soundtrackpro/

[22] P. Larsson, A. Väljamäe, D. Västfjäll, A. Tajadura-Jiménez, M. Kleiner, "Auditory-Induced Presence in Mixed Reality Environments and Related Technology", *in E. Dubois et al. (eds.), The Engineering of Mixed Reality systems, pp 143-163*. Springer-Verlag, London, 2010.