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Auralisations for Outdoor Noise Sources Environmental Auralisations

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ABSTRACT

Auralisations have for years been used in addition to mandatory noise maps and calculated number of noise exposed dwellings in the EAA-processes carried out by e.g. the Danish Road Directorate. Auralisations make it possible to get a realistic impression of the future noise during the planning of new roads or other important noise sources. Until now, only major road projects have been published using auralisations. Other noise sources like local roads, wind turbines, railways, tramways and light rails can obviously benefit from auralisations in communicating noise consequences to people influenced such as neighbours, decision makers etc.

Auralisations make it possible to aurally explain the mix of noise combined by two or even more noise sources. Normally, noise from various noise sources are treated and explained individually and have even different noise limits to meet. Auralisations should represent the total sound from all sources. This is much more realistic as the total sound will be perceived and experienced by the future neighbours.

This presentation deals primarily with auralisations made for road noise, but challenges of auralising other noise sources like wind turbines and the combined noise generated by various noise sources will be covered as well.

Keywords: Auralisation, Auralization, Environmental Noise

1. INTRODUCTION

Auralisations make it possible to hear how planned outdoor sound sources such as roads, wind turbines and railways will sound in different landscapes and situations. The most well-known analogy to this is a visualisation. Who will allow the construction of a new road or bridge without having seen in advance how the road will affect the landscape? But when it comes to sound and noise, you normally use visual measures like noise maps to explain the consequences. Why not use the ears?

Auralisations can also be used to clarify, how noise can vary in the surroundings due to different conditions. How does the road sound for example, in upwind or downwind situations, with an increased traffic volume or with a completely different traffic mix? Auralisations can answer all that.

From experience it is well-known that commonly used noise indicators like L_{den} are difficult to explain to layman; Hence noise is one of the issues that is most often discussed intensively, when planning new noisy sources. Naturally, the neighbours are concerned about, how the future noise will affect their lives – and by nature they will try to affect the project, so that noise is minimised.

From a planner's point of view, the authorities must provide as good and adequate information as possible, when the consequences of e.g. a road project are presented for the neighbours. This applies of course to the future noise level with respect to the noise limit, but certainly also to the explanation of possibilities and limitations to reduce the noise. Information on the effect of possible noise protection measures, such as noise barriers or noise reducing pavement, as well as changes in the speed and traffic volume, is important information. The neighbours and other stakeholders must be provided with most realistic and obtainable picture of the consequences at the planning stage. In

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addition to describing the consequences in words, pictures, graphics and tables, the benefit of auralisations can be used.

2. METHODOLOGY

The methodology used for creating auralisations has been:

1. Create noise source(s).
2. Create a propagations model for the sound in the wanted scenario.
3. Filter the sound source(s) by the calculated sound propagation transfer functions.
4. Mix the filtered sounds together.
5. Adding a soundscape providing a realistic and natural sound of the surroundings.

These five steps are described in the following paragraphs and illustrated in Figure 1. For road noise auralisations, the procedure is also described in detail in (1).

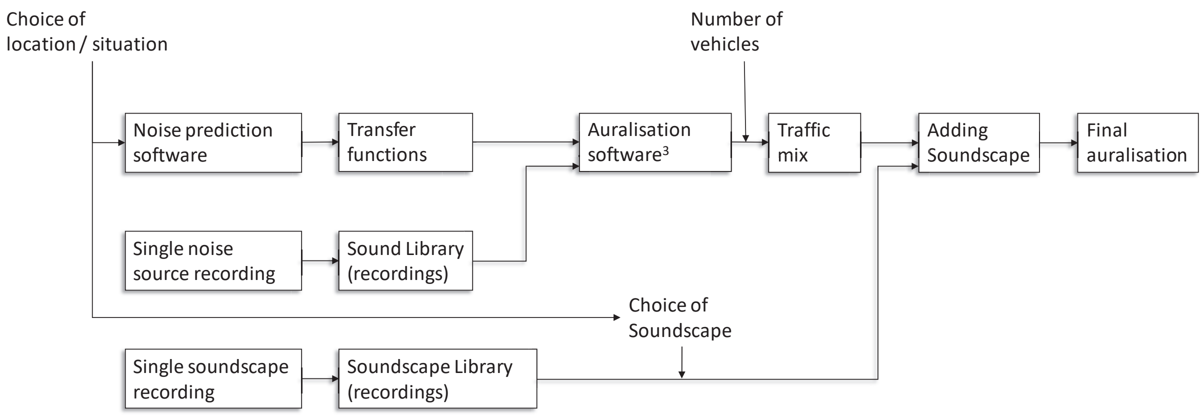

Figure 1 – Diagram of auralisation work flow (roads)

2.1 Creating a Source

The creation of noise sources has been accomplished by using a HATS (head-and-torso simulator) to make binaural recordings of single noise sources, such as a car passing by or a wind turbine. The benefit of this has been a high-fidelity sound recording of the source that sounds like the real source (in opposition to synthetic generated sound source). The challenges with this method are primarily background noise during the recording of the sound sources and limitations due to the recording position.

Due to background noise it is necessary to be very selective, when it comes to choosing the places to carry out the recordings. Avoiding background noise from other roads, singing birds etc. is essential, and therefore recordings have to be carried out relatively close to the road, i.e. 25 m, at evening and night time. Furthermore, there has to be low down wind speeds, i.e. from the noise source toward the HATS location (Figure 2).

The recording position poses a couple of limitations to the auralisation. The HATS has been setup pointing towards the noise source. When listening to the recorded signal, it appears to be located in front of the listener. Without using HRTF filtering it is not possible to virtually move the head around. The relative closeness to the road also sets a limit for, how far away from the road the auralisations sound realistic.

[3] The auralisation software (AuralizationLAB) is developed in-house with LabVIEW and takes care of the filtering of the noise.

Figure 2 – Photo of HATS location close to a motorway

Finally, it is only possible to auralise existing and available noise sources.

Recording time has been between 30 seconds – 2 minutes, depending on the noise source.

For vehicles that pass by, the needed recording time depends on the speed of the vehicle and the background noise in the auralised situation. The noise from the vehicle must have time to fall sufficiently below the noise from other noise sources (other vehicles, other types of noise sources or the soundscape noise).

For stationary noise sources such as wind turbines, the recording time has been as long as the final auralisation in order to avoid any discontinuities. Trying to loop a stationary (spatially stationary) sound source, where generated sound and the meteorological conditions continually shift, has proven it difficult to accomplish without discontinuities.

2.2 Sound Propagation

The propagation of sound from source to receiver is carried out twice: First for the recording situation and then for the auralised situation. The first propagation is only carried out once for each recording. The second propagation is carried out for each auralisation situation.

The propagation is carried out using a noise modelling software to create a computer model of the real situation and using Nord2000 (2) noise propagation method, the noise is propagated from source to receiver. In the situation with a moving sound source, the propagation is carried out for several point sources along the sound source path, i.e. each 10 m. The result of this is a 1/3 octave band spectrum for each source receiver position.

For each recording and new auralisation situation, the spectrum difference between auralisation situation and recording is obtained as the input to the next step.

2.3 Filtering Sound

The sound source is filtered using the calculated spectrum differences. In the case of stationary sources, this is quite trivial, since the whole sound is filtered with the same spectrum difference between auralised and recording situations.

In the case of moving sound sources, the binaurally recorded sound is split up into several sound clips corresponding to the time difference between source points (speed dependant) and carefully matched against the correct source receiver position. These sound clips are then filtered with the spectrum difference between the sound propagation spectrum for that point and the spectrum for the corresponding point in the recording situation. Finally, the filtered sound clips are put together again. Therefore, it is crucial that the position of the vehicle relative to the HATS position (in time) in the recording is known.

The result is realistic; An auralised sound file for each single source.

2.4 Mixing filtered Sounds

When auralising a road or a combination of sound sources, several files with auralised single sources are mixed together to create the situation aimed at e.g. busy afternoon traffic.

This is an important step, as it adds context to the sensation of “being there”.

For a situation with vehicles on a road, a semi-random, but somewhat even distribution of auralised single source files are mixed together. The mixing is performed by adding files with a specific time delay for each file. The time delay depends on what traffic flow, the auralisation has to illustrate. A somewhat random experience is achieved, as none of the recorded vehicles drives at identical speeds.

2.5 Adding the Soundscape

Finally, a suitable binaural soundscape with ambient noise that matches the situation that the auralisation is aimed at is added. Different soundscapes have been obtained using HATS at various places and with different noise events. One example was a situation, where a planned motorway was to be passing residential houses, and there was already a railway track nearby with passing trains. Using HATS recordings of the ambient sound, a very realistic binaural soundscape with natural ambient sounds was recorded with a train passing in the distance behind the HATS. This was added to a mix of vehicles passing by on the planned road in front of the auralised position. The result was an auralisation with recognizable and realistic ambient noise making the presentation trustworthy for the residents.

3. SOURCES

This auralisation methodology/technique has been used with different sources:

Road vehicles, such as cars, busses, trucks etc. have been used extensively in auralisations. Numerous recordings are performed on single vehicles passing by the HATS.

Trains, including normal trains and trams have also been used in a similar way that road vehicles have been recorded and used in auralisations.

Wind turbines are perhaps easiest to record, but only in one position and wind speed at a time. Since they are stationary, any change in relative angle between the direction of the nacelle and the auralisation point must be recorded separately.

4. EXPERIENCE

For years now, we have made auralisations used in the planning new roads in collaboration with the Danish Road Directorate, which is responsible for the major roads like motorways and interregional roads in Denmark. The auralisations have aimed at:

1) Presenting realistic and trustworthy noise levels for specific places in the surroundings like the resident’s garden or terrace, so one can hear, how the road will actually sound at one’s home.
2) Presenting the noise levels at specific distances using different noise reducing measures like barriers, special pavement etc.

The auralisations have been used at public hearings using calibrated headsets. Pictures of the landscape were presented on a screen simultaneous to simulate the context, i.e. the listener should imagine being at the exact location when hearing the auralisations. This was done using the screen with relevant pictures for each location (Figure 3).

Figure 3 – Auralisations presented at a public hearing using calibrated headphones

Another example was used at the public hearing, where there was a "noise café". Here, the public could – by themselves – activate the presentation using calibrated headsets and a video screen to visualise the situations.

Figure 4 – Auralisations presented at a public hearing. Photo from Danish Road Directorate

Finally, due to the great interest, we created a website with generic auralisations. Here the listeners could use it from their homes with their own equipment. This of course, makes it impossible to have full control over the calibration level and the quality of the playback system. However, we made a calibration procedure, allowing the listener to adjust the volume according to a speech signal, i.e. the listener should "adjust the volume so it sounds like a person speaking 1 meter in front of you". The website can be found here: https://acoustics.madebydelta.com/viden/auralisering-for-vejdirektoratet-2/road-noise-auralisations-2/

5. FUTURE WORK

There are several future developments that would expand the possibilities and improve the methodology. The ultimate scenario would be a very realistic VR-experience with both visualisation and auralisation combined. Before that goal can be reached, there are several challenges to overcome.

One major improvement that is being investigated is synthetic sources. The possibility to create high-fidelity synthetic noise sources would eliminate some of the limitations of using binaural recordings. There would be no issue with background noise and no limitations to the position of the auralised position. (i.e. we could auralise the sound from a future road in Australia in Denmark (if it was loud enough)). However, this requires the use of HRTF (head related transfer function). Synthetic sources with directivity would also allow for sources being placed in any direction relative to the receiver.

Using HRTF would make it possible to turn the listening position freely around, relative to the sound source and soundscape.

There are also possibilities to automate some of the (manual) steps in the process.

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