Environmental Noise Synthesis

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Introduction

According to the European directive 2000/49/CE environmental noise level shall be assessed to help reducing the exposure of environmental noise to citizens [1]. The data shall be presented graphically using maps. However, the degree of stress induced to people by noise is not solely dependent on its level but also depends i.e. on its information content. Thus, a more detailed and intuitive representation of the acoustical situation is desirable. This paper describes a system to synthesize the environmental noise to make the sound at an arbitrary public location audible. Like this, the environmental noise e.g. from different locations or at different time of day can be directly compared. The system may be used for virtual environments, too, to provide to the user a more realistic feeling about the virtual environment.

Approach

Our system consists of a data base of environmental sounds and a state machine that issues these sounds according to the situation at the location. The data needed for the state machine at each location consists of the type of noise sources present at the location, levels and statistics about the probability of their occurrences.

There were three main tasks for achieving the desired results. The first task was recording and cutting audio samples and then storing them in our database for later access. The second task was the software implementation of the system in Matlab. The third task, which is still ongoing, is to obtain realistic statistics about the occurrences of all types of noise at the locations under investigation.

Recording

Location Selection:

Before starting with recording, we had to choose appropriate recording locations. For car noise, there was a trade off between using quiet streets outside the city with less traffic, and locations in urban areas with higher traffic rate. In urban areas the recording of a specific number of cars took less time, however the audio quality suffered because of reverberation and other unexpected noise captured while recording. I.e. cutting the recordings was harder since often more than one car passed by at a time and caused overlap of the audio streams. Therefore, we decided to record car noise beside desert-roads. Like this the sound was captured under a very low reverberant and rather quiet conditions. One of the selected locations is shown in Figure 1.

Figure 1: Example of one of the recording locations.

Equipment Setup:

To record samples of various ambient noise scenarios 8 boundary layer microphones of the type AKG C562 CM were used. The signals were first fed to two 4-channel microphone amplifiers (RME Quadmic), and then to a multi-channel analog-to-digital converter (RME Multiface).

The microphones were attached to 10 cm wide wooden boards. We used a linear, equi-distant array with 1 meter distance between the microphones. Wind noise and dust was avoided by placing a thin foam layer over the microphone capsules. A sample rate of 48 kHz and 24 bit quantization was used for all recordings.

Audio File System

After finalizing the recording sessions the samples were manually cut and stored in a data base, sorted according to their types.

After first tests of the overall system using point source noise samples, the gaps between the instances were irritating to the listeners. Therefore we also recorded additional appropriate background noise files to hide these gaps. They made the simulation much more realistic.

Two major types of audio files are therefore stored in the data base:

- *Individual point source noise:* Samples are available from cars, trucks, trains, motorcycles, and airplanes.
- *The background noise:* We recorded talking people (crowd), birds chirping, dogs barking, crickets, and wind.

System Design

The block diagram of the system, as shown in Figure 2, is divided into three parts. The first part is the graphical user interface. The second part is the system engine. The data from the system engine is then fed to the sound engine which plays the audio samples.

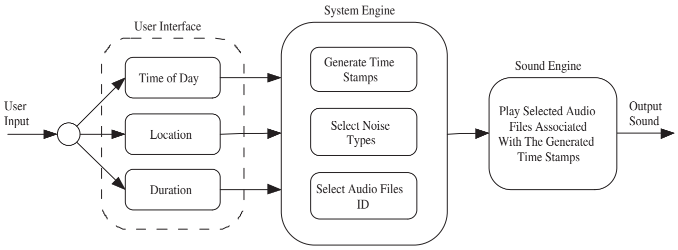

Figure 2: System Flow Diagram.

Graphical User Interface

We designed a graphical user interface to select general parameters of the virtual environment, like the time of day, the location and the duration for the simulation.

System Engine

The system engine reads the input parameters from the user interface and generates a matrix that contains the time stamps. It not only determines the type of sound to be played but also decides on which audio sample of this type should be played.

All these random output parameters are generated using a state machine. It is implemented using a Markov chain. Each state uses different probabilistic distributions that are dependent on the time and location.

An example of the output matrix is shown in Figure 3; each column defines the start of an audio sample with the time to be played in the first row, the noise type in the second and the file-id in the third row, respectively.

1	5	26	44	53	56	77	79	91	102
94	5	6	7	7	94	2	5	4	3
1	5	8	2	4	1	6	11	4	38

Figure 3: Output Matrix Example

Sound Engine

The sound engine is used to play the selected audio samples. It uses the matrix generated from the system engine to select the sound samples from the data base. It then plays the samples at the predefined time and adds the signals of several samples in case of overlapping.

Results

Although representing acoustics using images or plots is against the objective of this paper, some results shall be visualized here. In Figure 4 we show the envelope of the time signal for 3 different scenarios. Figure 4 A) shows a simulation for a location outside a city in the afternoon without added ambient background noise. The gaps of silence between passing cars are very obvious. Figure 4 B) represents a simulation for downtown at night with cars passing more frequent compared to the first simulation. Figure 4 C) finally shows a downtown situation during rush hour. Much noise with the most traffic rate is given here.

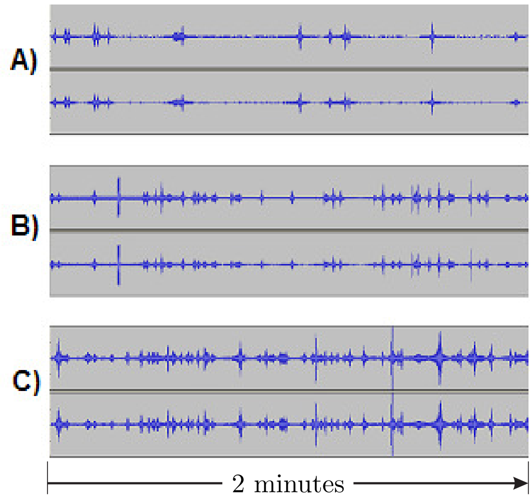

Figure 4: Waveform for Scenarios A, B and C

Conclusion

This paper describes the first implementation of an environmental noise synthesis. We want to apply it next to acoustic maps and combine it with street view applications. The system we described will improve the user's experience for many virtual reality applications by adding realistic ambient sound.

With the final version of the system the ambient noise at any arbitrary location within a city shall become audible by selecting the corresponding position on a map. Even simulations of future modifications of the environment shall be possible at a later stage.

References

[1] Commission Of The European Communities. *Directive Of The European Parliament and Of The Council relating to the Assessment and Management of Environmental Noise*, 2000