Methods for the identification of background noises and noise events

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Introduction

Noise, emitted by traffic, industry and leisure activities is an important environmental problem. It is also responsible for citizens' increasing complaints. Being exposed to e.g. aircraft- and traffic noises over a certain period of time, health damages like high blood pressure, a diminution of infection defence or increasing risks of heart attacks can occur [1]. The impact on health by noise exposure depends on its intensity, frequency of occurrence, duration and the spectral composition of the particular noise [2].

Monitoring the statutory limit values of noise pollution requires long-term noise measurements. Within a research project funded by the BMBF at Cologne University of Applied Sciences in cooperation with deBAKOM GmbH (Odenthal) innovative methods of digital audio processing for automated identification of noise contribution emitted from different sources are currently being investigated and developed.

In particular the project is focused on aircraft noises. Several audio sources have to be separated by applying adequate methods and algorithms to gain a conclusion in terms of aircraft noise's contribution to the total noise. Spectral and temporal attributes of the audio-signal are analysed and assigned to particular classes of noises. Previous approaches in this field have been carried out by, e.g., "Aircraft sound level measurements in residential areas using sound source separation" [5].

Basics

In state-of-the-art systems the common method of environment noise analysis is to manually analyse long-term noise recordings (e.g. for a few days) nearby an airport and to document the temporal periods of aircraft noise contribution.

The objective of the method presented in this paper is to automatically identify the periods of aircraft contribution recreating the human ability to recognise and separate noises by evaluation of some relevant parameters.

The development of appropriate audio processing algorithms shall be done in MATLAB. First the audio signals are analysed concerning spectral and temporal characteristics. These characteristics form features. The calculation of features is helpful for further interpretation and classification of noise.

The features are compared and those that comply with the following criteria are selected:

- Low variance of the features within one class
- High distances between the classes

Figure 1 shows the temporal distribution of one feature. This distribution is obtained by windowing and calculation of the feature within each time bin.

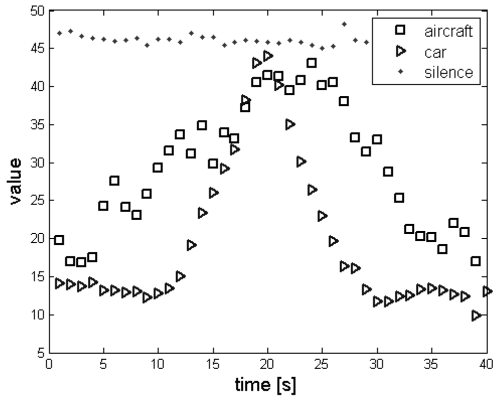

Figure 1: Temporal distribution of feature vectors for different noise classes (aircraft, car, silence).

Thereafter it is sufficient to elect the most appropriate features by dint of visual inspection. The elected features are then used for further steps in the process.

Features

The identified features describe the properties of the audio signal and can be used for signal identification. They are divided into temporal and spectral parameters, e.g.:

temporal	spectral
Autocorrelation function	Spectrum
Amplitude characteristic	Cepstrum
Sound pressure level	Mel-frequency cepstrum
Linear predictive coding	Line spectral frequencies

Applying the above mentioned feature comparison criteria to temporal and spectral parameters some adequate features for signal detection can be derived. By visual inspection, following features turned out as significant for aircraft noise:

- Spectrum – centre of gravity
- Cepstrum – variation
- Cepstrum – kurtosis
- Cepstrum – skewness
- Amplitude statistic – width

- Amplitude statistic – symmetry
- Amplitude variation
- Linear predictive coding – skewness
- Time average sound pressure level

Identification with Hidden-Markov-Models

The Hidden-Markov-Model is a statistical model, which can be used for temporal pattern recognition. It contains different states and transition probabilities between the states. The HMM facilitates including temporal characteristics of the signal to the identification process.

The HMM is trained with reference signals of the specific class. For each class a different HMM has to be applied. For aircraft noise detection e.g. following classes are included:

- Aircraft noise
- Car noise
- Silence (background noise)

As silence and car noise will definitely appear in the noise measurements they are assigned to own classes and hence own HMMs. Each of those HMMs is fed with the analysis signals and returns a probability of its dedicated class.

The highest probability decides to which of the classes the signal can be assigned.

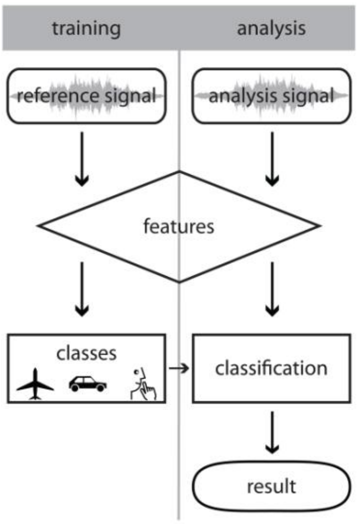

Figure 2: Model of identification to detect aircraft noise [3]

Identification with vector comparison

Another method for identification is a comparison of the analysis signal with a reference cluster.

Initially the features of a large amount of reference signals are calculated. Those features are grouped to different clusters. Each cluster represents one class. Furthermore the analysis signal is decomposed to vectors of the same features, which are compared to the reference cluster.

Different method-types of distance calculation yield the distance between signal vectors and reference cluster. The lowest distance determines the identified class [3].

Next steps

The actual focus is put on the identification method based on the HMM. In simulations with implemented HMMs automated detection rates of >90% can already be achieved for manually selected aircraft noise signals.

To analyse the behaviour of the applied algorithms at low signal levels, background noise was added in different ratios to the aircraft noise. We describe this ratio as the SSR (Signal to Silence Ratio). The signal is subdivided into time frames of one second. The SSR has been defined as the quotient of the highest frame average level of all time frames and the total average level of the background noise. It turned out that noise significantly reduces the detection rate both when using the HMM or when using the vector comparison. Thus, currently the applicability of appropriate noise reduction algorithms is currently investigated [4]. First results indicate that the HMMs can deliver a detection rate >90% up to a SSR of +12dB. Thus it is even possible to detect aircrafts with a low signal level compared to background noise.

If classes are only detected with low probability the detection should be marked as a low significance result.

Perspective

A comparison of both presented methods will permit a closer evaluation and provide us with practical results for a future software implementation.

In addition the methods and algorithms for the aircraft noise detection should be adapted and extended for the identification of other noise sources (e.g. traffic noise, machine noise, etc.).

References

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