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Automatic segmentation of traffic noise

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The state of the art in audio source separation reflects a growing interest towards developing tools oriented to speech and music applications. However, its application to the study of noise, and more specifically to the study of traffic noise, is scarce. The source separation in this work environment is a key process for subsequent classification and analysis, and has motivated the present research carried out.

This paper is intended to present, therefore, the different strategies followed in the implementation of an automatic segmentator for traffic noise, focusing the research on two main aspects: The removal of components of noise unrelated with the sources of study and, by other side, the detection and separation of audio sources acquired. For this purpose, measures of traffic noise are made and results are analyzed for the running system, achieving a high level of performance in real work conditions.

1 Introduction

Traffic noise is one of the health areas that produces more inconveniences for the actual society. For this reason, more resources are dedicated to combat it, being scarce however, the number of researchs focused on obtaining efficient detection and classification techniques. In this scenary, this paper aims to present the main results obtained in designing an automatic system for detection, segmentation and classification for sources of traffic noise.

This research begins by describing aspects of the characterization of this kind of noise, information necessary for processing the signals acquired. Then, it is followed by describying the problem of blind source separation applied to traffic noise by using ICA *"Independent Component Analysis"* techniques. Finally, results are analized and it is shown how the prior application of spectral noise suppression techniques significantly improve the separation between classes.

2 Traffic noise characterization of a individual vehicle

Traffic noise can be considered as a composite noise, generated by the combination of individual contributions of noise generated by each vehicle. The present investigation is carried out using a definition of classes according to three categories: Motorcycles, cars and trucks. To characterize each of these classes, it will be analysed the characteristics of the signal noise generated by vehicles into temporal and spectral domains. This complex noise signal results from the contribution of different sources located in each individual vehicle..

2.1 Sources identification

In the analysis of noise generated by a motor vehicle, in good condition for use, it can be observed that it is mainly determined by the contribution of four different types of noise:

- Engine noise
- Aerodinamics noise
- Exhaust noise
- Tired noise

Engine noise: Sources involved in the generation of engine noise are very different (engine, suspension, rakes,…).
Then, it's necesary to carry out a study through an analysis of their vibratory behavior.

Aerodinamics noise: It's caused by the turbulence caused to penetrate the vehicle in the middle air. These turbulence depend mainly on the geometry of the chassis and the speed at which the vehicle travels.

Exhaust noise: The exhaust gases that incorporates the vehicle provides a high level of contribution to the overall noise generated. In designing this system is particularly important to know the combination of the type of silencers incorporated (reactive, abpsortive), sharply reducing the level of noise induced.

Tired noise: The generation of this type of noise is determined by airborne and structural propagation due to tire contact with the surface of pavement. Over 50 Km/h (motorcycles and cars) and 70 Km/h (trucks), the noise generated by a vehicle is characterized mainly by tired noise

Finally, the noise generated due to a combination of sources described, will be affected by the noise propagation conditions to the receiver, the directivity pattern of the vehicle, the distance at which it is from the source , and the Doppler effect. The resulting noise characterize each type of vehicle, allowing their classification through an analysis in time and frequency of their behavior.

2.2 Traffic noise features

In terms of spectral analysis, noise generated by a motor vehicle can be characterized by its spectral density of energy. An analysis in frequency of this energy distribution reveals the existence of a combination of a wideband stochastic processes, mainly caused by the turbulence generated in the engine, with deterministic processes most important characterized spectrally by harmonic components of noise generated in the cmbustion process. The spectral influence of these components will depend, therefore, of changes of gear, speed and acceleration produced in the vehicle, as well as the spatial distribution of all noise sources located in the engine.

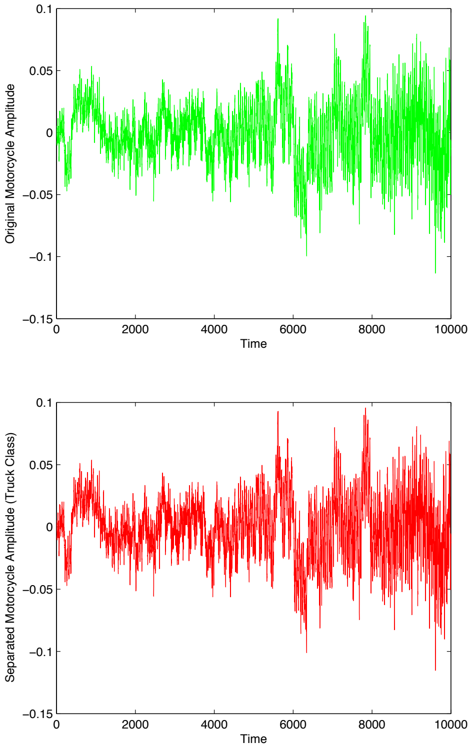
In the time domain, on the other hand, is better to carry out a characterization of statistical time series adquired. From this perspective, the temporal evolution of noise generated by an individual vehicle is characterized by a process clearly not stationary but, through a temporary localized analysis, the resulting sequence can be considered quasistacionary.

3 BSS. Blind separation of traffic noise sources

Doubt that the problem of separation of traffic noise sources, the original signals can not be observed and is unknown as they have been mixed, extraction of signals components of the mixture becomes a blind process. From a mathematical point of view, there is still solution to the problem as long as the input signals are statistically independent.

3.1 ICA. Independent component analysis

An efficient method of finding a solution to the problem of BSS described above, is the calculation of the matrix to minimize the statistical dependence of a set of components.



,Fig.1 Example of the temporal series representation of a noise signal obtained after the BSS process applied.

Then, it's necessary to have, at least, the same number of mixtures of sources and that, at most, only one of the signals having a gaussian distribution. The mxture equation is then defined as Eq. (1), where A is the mixture matrix, and $s(t)$ e $x(t)$ are the vector that contain the sources and the observations.

$$x(t) = A \cdot s(t) \qquad (1)$$

The solution, then, will be to find the separation matrix B, solution for Eq.(2), where $y(t)$ will be a sources vector stimation $x(t)$.

$$y(t) = B \cdot x(t) \qquad (2)$$

4 Experimental results

To evaluate the performance of the system implemented, an analysis of the results is made for three kinds of categories of vehicles: motorcycles, cars and trucks. The separate signal is compared with the original one, after normalizing the samples values, by calculating power spectral density, the scatter of statistical samples and the mean squared error committed in the process.

By means of the analysis carried out, it is obtained a strong dependence with the number of defined classes, as it will be seen below.

4.1 Between classes and within class analysis

For a between classes study, the obtained results show a correct behavior of the ICA method, getting the blind separation with a sufficient degree of independence between signals, marked by an uneven distribution of power spectral density, as is showed in Fig .2. As a result, it is observed a high degree of statistical correlation, Fig.4, and a smaller mean square error between both time series, Table 1. The variability in the spectral distribution of the harmonic components, for each type of vehicle, reflects a minor separation of the cars class in relation to the rest of classes, translating it into a lower dependence of the signals to separate.

For a same class, the similarity in the spectral distribution of energy of the signals to separate, Fig.3, diminishes the benefits in the application of ICA, as it is showed in the Fig. 5 and Table 2. The worse case is obtained for the trucks class, with a greater spectral concentration in LF

4.2 Noise supression

In the presence of other signals, not related to the signals of interest, the application of techniques of spectral noise subtraction allows obtain a classification generally more robust. This technique is widely used in noisy environments, with voice signals, music or telephony,

In the case of traffic noise, the noise spectral suppression, applies greater spectral separation in low frequency of mixed signals, which translates into greater independence in input signals for ICA algorithm. This improves significantly the process of classification of the results, Fig.6 and Table 2, with increasing improvements in the separation of signals from the same class, especially into the truck class.

5 Results ilustrations

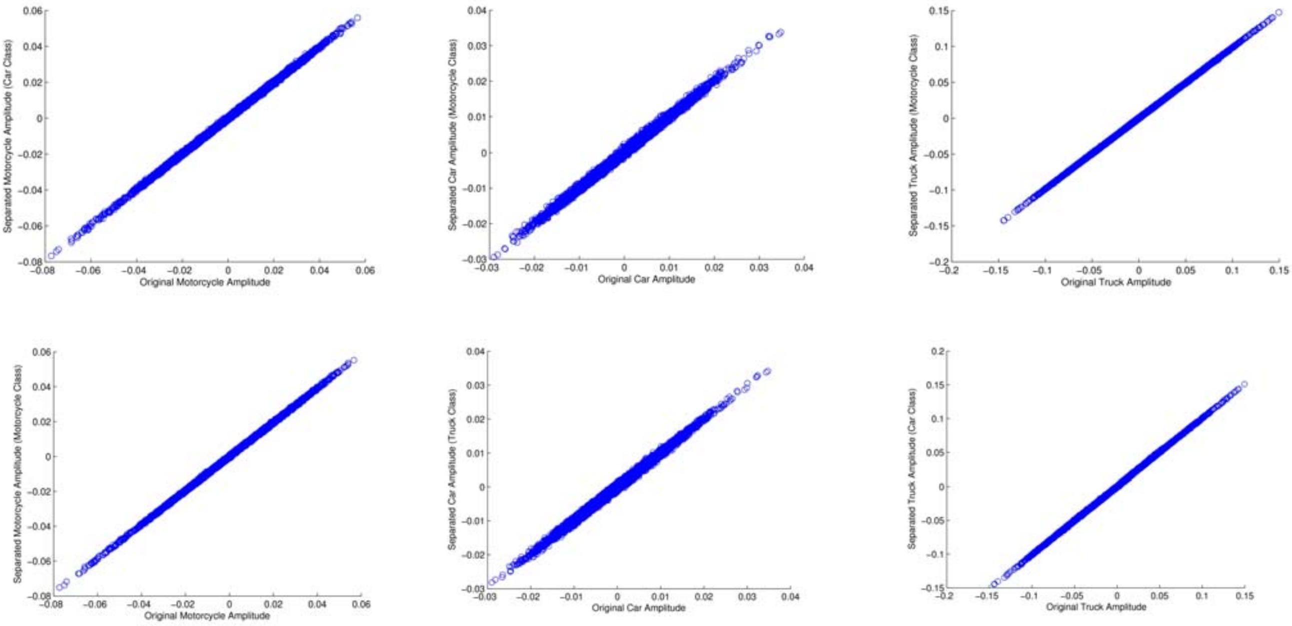


Fig.2 Scatter representation for statistical correlation test of the separation performance between classes.

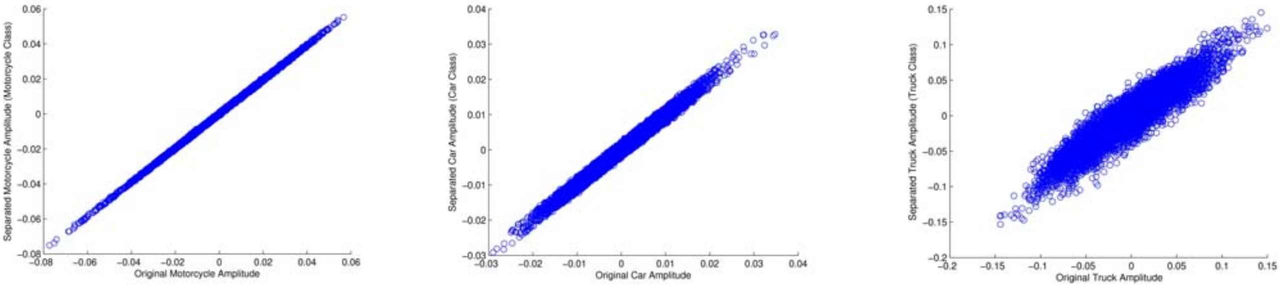


Fig.3 Scatter representation for statistical correlation test of the separation performance within class.

Mean quadratic error	Classes		
	Motorcycle	Cars	Trucks
Motorcycle noise	$5{,}4908\cdot10^{-6}$	$1{,}0698\cdot10^{-6}$	$3{,}8165\cdot10^{-7}$
Car noise	$2{,}8623\cdot10^{-6}$	$4{,}4961\cdot10^{-5}$	$3{,}7199\cdot10^{-6}$
Truck noise	$1{,}1101\cdot10^{-7}$	$1{,}6830\cdot10^{-6}$	$2{,}9287\cdot10^{-4}$

Table 1 Mean square error in noise signal separation for the BSS process applied.

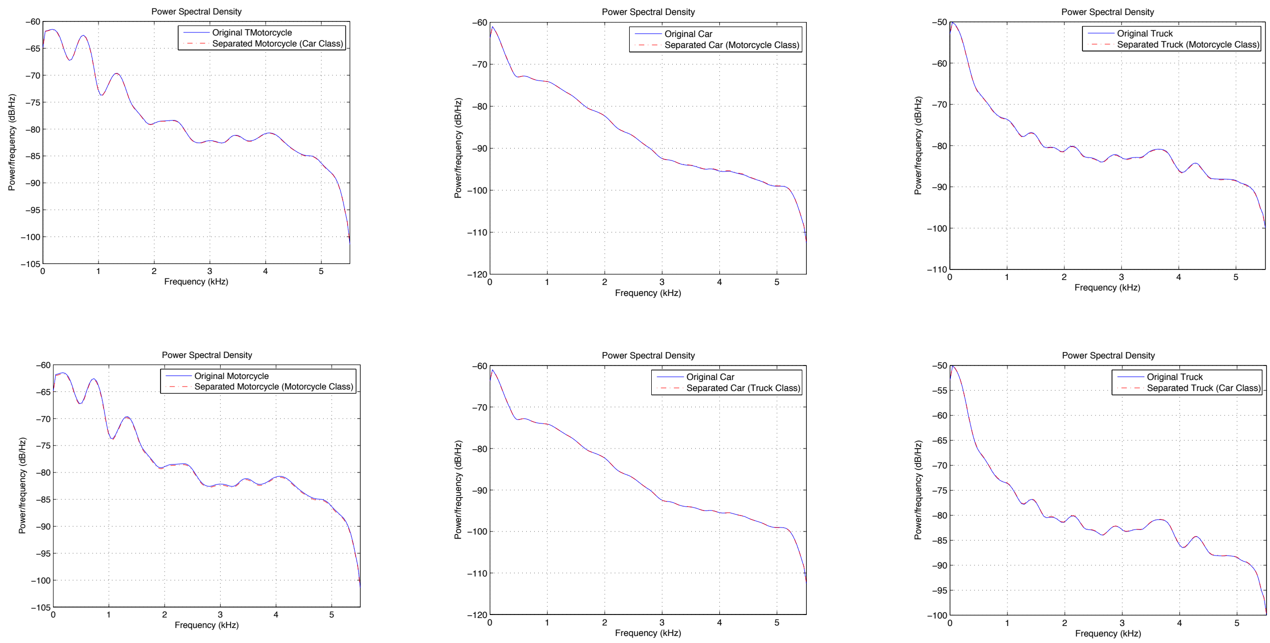


Fig.4 Power spectral density representation for test the separation performance between classes.

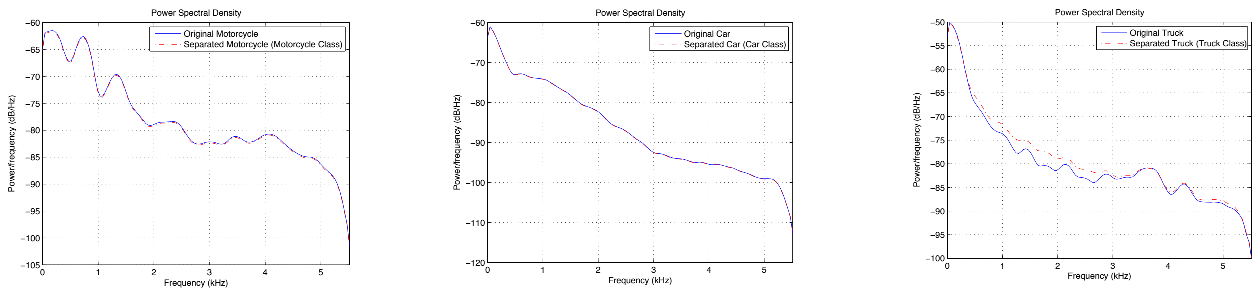


Fig.5 Power spectral density representation for test the separation performance within class.

Mean quadratic error	Classes		
	Motorcycle	Cars	Trucks
Motorcycle noise	$4{,}2153\cdot10^{-6}$	-	-
Car noise	-	$3{,}5748\cdot10^{-6}$	-
Truck noise	-	-	$5{,}6534\cdot10^{-6}$

Table 2 Mean square error in noise signal separation for the BSS process applied, after noise supression of unrelated components.

6 Conclusions

It has been applied the independent components analysis method fot traffic noise classification into noisy environments. Interesting results are extracted from the analysis carried out.

On the one hand, for traffic noise sources separation, the results show a high degree of similarity between the originasl and the signas extracted from mix, improving benefits for withinclass separation front of the separation between classes. In this sense, it is found that under a proper definition of all classes, the efficiency of the method is mainly due to good approximation of ICA hipotesis. By other hand, it has been showed that the prior application of spectral noise suppression techniques dramatically improve performance for separation within class.

Acknowledgments

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