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Technical Note

Unattended acoustic events classification at the vicinity of airports

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ABSTRACT

This paper describes a method for the automatic identification of acoustic events using a weighted average of sound pressure and sound intensity measured at the vicinity of airports. The classification is based on the combination of different parameters using a technique conceptually similar to the sensor fusion: the indications of different classifiers are merged using the classification uncertainty as a figure of merit. The method uses the results of a training phase for the observation of statistical distributions of sound pressure and sound intensity related parameters. The different parameters' weights are computed analyzing the overlap of probability distributions of takeoffs and landings, so that more relevance is given to the quantities presenting a low risk of misclassification. The proposed method does not require any arbitrary assumption about the parameter effectiveness, given that the indications of multiple (potentially infinite) classifiers can be merged together with weights that minimize the chance of misclassification. The method has been validated with measurements performed at the Milan Malpensa airport (Italy). Results outlined that the proposed classification criterion correctly identifies approximately 99% of events.

1. Introduction

The social impact of airport noise is relevant [1,2] and the public request for quieter airports lead to develop a strict legislation based on the compulsory noise monitoring which usually combine information deriving from noise level meters and radars. As underlined by the ISO 20906 [3] and in the literature [4,5], noise measurements close to the airports often involve different noise sources; complex logics are therefore needed to separate the aircraft sound events from spurious sources. In many situations, the uncertainty related to the identification of aircraft-related events is large [4], given the wide discretional margins that can be chosen in the ISO 20906 procedure. Consequently, benefits deriving from an automatic detection can be important.

The problem of automatic acoustic event recognition has already been faced in the literature: Pfeiffer et al. [6] presented algorithms aimed to recognize noise-generating events, concluding that time-frequency patterns are difficult to investigate and claiming that the more like to human hearing a method is, the more effective it turns out to be. Andringa et al. proposed the use cochleograms for the identification of aircraft-related events in residential areas [7]; results demonstrated that even in the case when the aircraft noise was 5 dB larger than the background, the detection performances were comparable to the human listeners. The recognition of ground vehicles noise (cars, trucks, etc.) was performed using Short Time Fourier Transform (STFT) [8]; results outlined that diverse events must present significant differences in order to get distinguished.

The possibility of separating the noise sources depending on their position was experimentally investigated at the vicinity of Milan Malpensa Airport [5] using a 3D sound intensity probe [9]. Results allowed discriminating the acoustic contribution of the aircraft from other sources inside the airport; the 3D probe position prevented from distinguishing between takeoffs and landings. Genescà et al. [10] separated the aircraft noise time history from that of extraneous noise sources using a microphone array, evidencing that the sound source position can be used to discriminate different aircraft-related acoustic events.

Several recent literature studies used the noise pattern recognition for the identification of aircraft takeoffs [11,12]; results evidenced that approximately 90% of events are correctly classified using a multimodal autoregressive model. A real time method for the identification of the aircraft's sounds has been proposed in Ref. [13]. A monitoring unit allowed recognizing approximately 93% of events, independently on the measurement location and on the soundscape.

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This paper aims to propose a novel method for the identification of aircraft-related acoustic events (takeoffs and landings) using acoustical quantities. The main idea of the proposed method is to merge the indications of existing criteria (based on the noise time history, spectrum, cepstrum and sound intensity direction) using a linear classifier with multiple thresholds computed starting from the results of a training phase. The weights of the different parameters minimize the chance of misclassification, using the measurement uncertainty as a figure of merit. The proposed method is described in Section 2. The results of measurements performed at the Milan Malpensa airport (Italy) are presented in Section 3 and the method performances is discussed in Section 4. The paper is eventually concluded in Section 5.

2. Method

As previously mentioned, the method is conceptually similar to the sensor fusion [14], a technique in which measurements of different sensors measuring the same phenomenon are merged together with weights that are inversely proportional to the sensors' uncertainty. In our case, the indication of different classification methods are merged together to obtain a unique (and more reliable) classifier. The uncertainty of each method is given by the chance of misclassification, that can be identified during a training phase with statistical analyses.

The proposed method for the automatic events recognition is therefore based on three steps:

1. Feature selection: identification of parameters derived from sound pressure and sound intensity that can be used to distinguish takeoffs from landings.
2. Training of a classification model that is the sum of:
   a. Statistical analysis on real measurement data for the determination of values assumed by the previously described parameters.
   b. Identification of the decision function, i.e. of a threshold for each parameter to discriminate between takeoffs and landings using statistical criteria.
   c. Combination of different parameters using the measurement uncertainty to identify the weight which minimize the risk of misclassification.
3. Testing, which involves the verification of the actual method performances: use of the automatic procedure for the (known) event recognition in conditions similar to the training ones.

There are potentially infinite criteria that can be used to discriminate takeoffs and landings using sound pressure and sound intensity measurements, but their efficiency often depends on the measurement location and on the aircraft noise characteristics. Consequently, the questions that the experimenter tries to answer are

i. Which are the (most efficient) parameters allowing to classify different acoustic events (for instance, takeoffs and landings)?
ii. Which is the thresholds for each parameter?

The proposed approach merges the indications of potentially infinite parameters and, for each of them, computes the threshold that minimizes the chance of misclassification. In the next sections, we will describe different parameters that are commonly used for the analysis of airport noise and then we will explain how to combine multiple indications using a unique classifier.

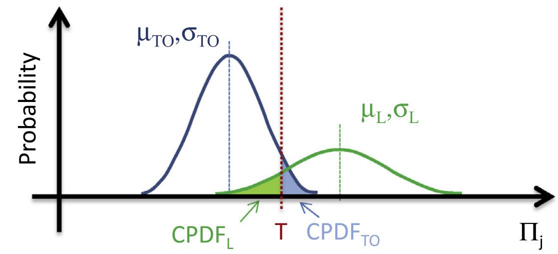

Fig. 1. Identification of the optimal threshold for the classification of takeoffs and landings.

2.1. Thresholds identification

Independently from the measurement point location and on the noise characteristics, it is always possible to derive a certain number n of parameters (Π) describing the acoustic event. With the term parameter, (hereinafter Π) we refer to any numerical quantity extracted from the signal as, for instance, the maximum sound pressure level or the event duration. Each time that an aircraft passes in front of the measurement point, the parameter Π_j assumes a value π_j. The identification of a threshold T_j that allows identifying if the event is a takeoff or a landing is often problematic, but with the proposed method, T_j is determined analyzing the probability distributions of the random variable π_j during takeoffs and landings.

Let us consider a single parameter (for notation clarity the index j will be omitted) and its takeoff and landing populations Π_{TO} and Π_L. For simplicity, let us suppose that the two populations can be approximated with Gaussian distributions,[1] as shown in Fig. 1. In this case, takeoff data can be summarized by the takeoff mean μ_{TO} and by the takeoff standard deviation σ_{TO}. Similarly, landings are summarized by the landings mean μ_L and by the landings standard deviation σ_L.

The proposed criterion for the calculation of T is based on the minimization of the probability of misclassification. If we consider that the *a priori* probability of the take offs is equal to the *a priori* probability of landing (and both are equal to 50%), the optimal T is the one for which the cumulative probability density function (CPDF) "external" to the threshold is equal for takeoffs and landings [15]. With reference to the above figure, such a condition is given by:

$$\frac{\mu_L - T}{\sigma_L} = \frac{T - \mu_{TO}}{\sigma_{TO}} \tag{1}$$

The threshold T is therefore

$$T = \frac{\mu_L \sigma_{TO} + \mu_{TO} \sigma_L}{\sigma_L + \sigma_{TO}} \tag{2}$$

The above equation indicates that

- T assumes a numerical value between the mean of takeoffs and the mean of landings.
- T is closer to the mean of the population with the lower relative standard deviation.

If takeoff and landing distributions are not Gaussian, the threshold T has to be identified from the experimentally identified CPDF percentiles so that the probability of misclassification is equal for takeoffs and landings.

[1] Implications of such a choice will be discussed at the end of this paragraph.