한국소음진동공학회 2001년도 춘계학술대회논문집, pp. 1217~1220.

NEW TOOLS FOR "SQUEAK-AND-RATTLE" AUTOMATIC DETECTION

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1. INTRODUCTION

The discomfort due to squeaks and rattles appearance inside the car has serious repercussions on consumer's opinion about acoustic quality of the vehicle and may change his economical behaviour. In this paper, we present a set of tools for squeaks and rattles processing implemented on a PC-based two channels analyser and grouped in a friendly interface. The toolkit includes events detectors, pre-processing signal analysis and automatic recognition solution, based on the MADRAS methodology (1). Different analysis methods based on innovative psychoacoustical tools and classical spectral analysis will be compared.

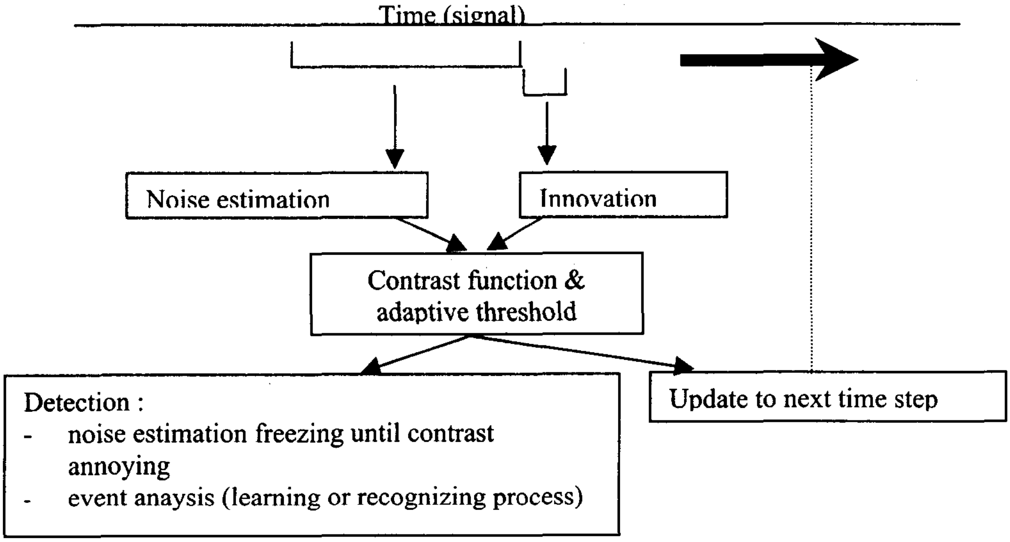
2. GLOBAL ARCHITECTURE

A squeak or a rattle is usually a very short event (a few milliseconds), mixed with a relatively high background noise at low frequencies. The transient nature of such signals requires particularly well adapted processing tools, both for detection and analysis. The described tool was intended to be light and easy to use (on the road, by car dealers and customers). It appeared necessary to build a selective event recorder, able to detect pertinent events and providing a very good recording quality for measuring purposes. The recorded squeak and rattle signals are then analysed using a robust psychoacoustical model, well suiting each particular signal type. A special learning protocol was developed to store relevant signal descriptors in a data base. This base was then applied to the actual squeak and rattle recognition in situ.

Step 1: Detection

The events to be detected have a strongly transient signature. The method chosen is based on a comparison of two estimators operating on two time windows. The long one, 500 ms, was used for the estimation of the parameters on the steady elements of the signal (background noise). The short one, 40 ms, was the used for the calculation of fast changing elements (innovating window).

Different estimators may be chosen in each of the above windows (FFT, specific loudness, global level, etc.). A contrast function between the two sliding estimators marks the time moments of occurring events and triggers the subsequent adequate analysis. This function consists of a comparison between the descriptors of the innovation (short window) and the descriptors of the background noise. The application zone of the descriptors can be chosen and adapted to any particular situation (e.g. frequency range). A user defined threshold is then applied as a criterion of the detection.

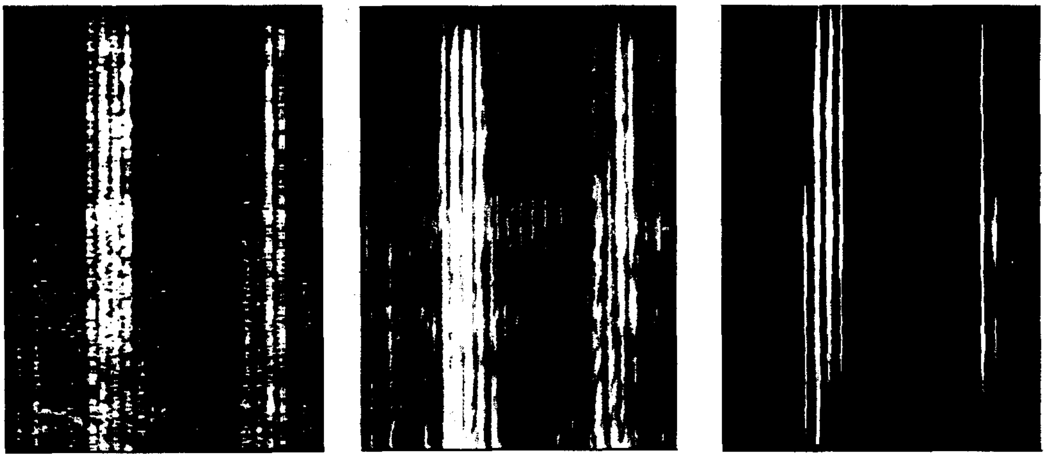


Step 2: Analysis

The purpose of this step is to prepare a set of parameters giving the best description of the signal from the point of view of the recognition that follows. Several estimators have been used to achieve this target: digital spectral analysis in 1/N of octave (N=1, 3, 6, 12, 24 and 48), specific loudness spectrum, per bark (a battery of 24 digital filters), a model of ear (see chapter 3), and multiple scale analysis (Mallat wavelets).

The analysis method should be adapted individually to each signal. However, a trend appeared after multiple tests on different squeak and rattle signals: the loudness per bark spectrum seems to be the most robust and the most pertinent event descriptor, and the information extracted from the signal fits well the purpose of the recognition.

The example below shows three different analysis results (time-frequency) on a 2 seconds of signal of a seatbelt retractor. The spectral range of interest is between 2000 and 9500 Hz. Two bursts (fours clicks followed by two clicks) have been detected and analysed. A classical frequency analysis (left), a 1/12 octave analysis (middle) and a loudness per bark spectra (right) are shown. The latter gives the most concise and background independent description of the acoustic situation, improving the performance of recognition algorithms.



Step 3: Learning and recognition processes

In each analysis method, whether it is explicitly chosen by the operator or automatically applied by the program, a vector of values is a descriptor of the detected event. Usually, this vector is composed of spectral values.

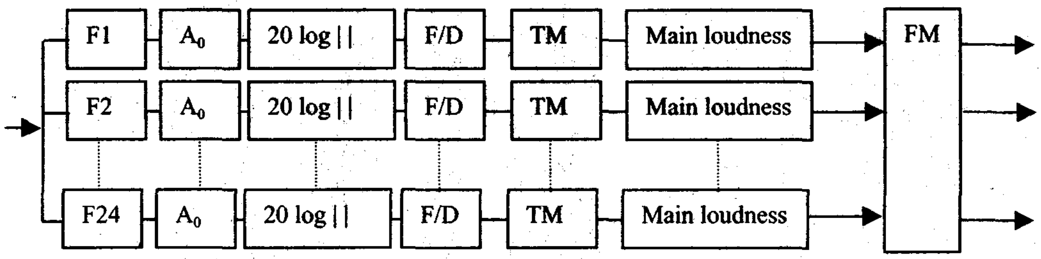
The learning protocol consists of presenting to the competent operator a series of vectors (events). First of all, each time the operator recognises the origin of the event (gives a label). But he also chooses the frequency range to be applied. A tolerance radius is then associated with each dimension of the vector (frequency band). This radius is based on the statistical spread of values in the population of examined events. The set of the above parameters (the skyline, as it often appears graphically) is saved in the data base at the end of the learning session. Experience shows that for events having a high similarity degree need only ten learning samples to give a stable and pertinent skyline.

After all these preparing steps the recognition now simply consists of comparing the newly detected events to the skylines from the data base. The program decides whether an event belongs to a given class when its describing vector is included in the skyline of the class in terms of least square value par vector dimension.

3. PSYCHOACOUSTICAL MODEL OF THE EAR

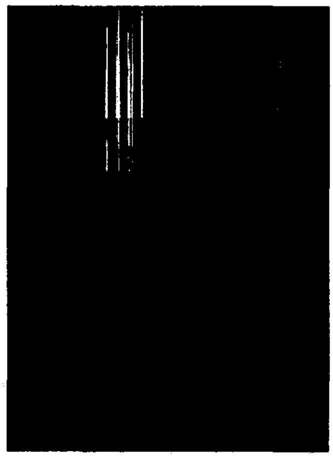
The loudness per bark analysis is done with a battery of 24 digital filters. Their cut-off frequencies are those of critical bands. Such stationary model takes into account the frequency masking of the human ear, but not the time domain masking. This time masking is particularly important in the case of a high level exciting signal in high frequencies, like most of the squeak and rattle signals. Thus, the non-stationary ear model has been applied, involving both the classical frequency masking and time masking.

The operation of the model can be presented by the following chart flow:



This scheme (called cochleogram) is based upon the classical loudness calculation (3) taking into account the transfer function A_0 of the inner ear in each of the 24 critical bands and the diffuse field correction factor F/D. The originality of the adopted model consists both in taking an original family of filters and in integrating an adapted temporal masking process. The cochleogram uses Gammatone filters [4], which present rejection ratio similar to human cochle. The time masking TM is composed by two "RC" filters to integrate signal in rising and decreasing slopes, with time constants depending on the bark band considered.

The analysis of the signal presented above (seatbelt retractor) shows a better dynamics, emphasising the pertinent patterns in the time-frequency plane. The learning process (the building of the skyline) is significantly easier.



4. CONCLUSION

The system presented allows an automatic detection of squeaks and rattles in the acoustic signal, and a recognition of their origin. The integration of a non-stationary ear model neatly improves the performances of the algorithms making possible practical in situ applications. A series of extended validation tests is being performed to check the limitations of the system and to define possible directions for future development.

References

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