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A SYSTEMATIC METHODOLOGY TO ASSESS SUBJECTIVE HUMAN PERCEPTION FROM OBJECTIVE PHYSICAL MEASUREMENTS WITH SEVERAL INDUSTRIAL APPLICATIONS IN TRANSPORT AND ENVIRONMENT

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ABSTRACT
This paper deals with the way to build a relationship between objective measurements (from physical sensors) and subjective assessments (expert evaluations). METRAVIB RDS has carried out several studies concerning the vibro-acoustic annoyance, the quotation of car engine combustion noise, the gear box changes comfort and, more recently, the evaluation of car drivers "workload" for automotive safety. On these latter topics, the developments could be brought up to the stage of dedicated devices, including sensors and real-time onboard processing units, respectively the so-called COMBUSTIOMETRE and the Driver Situation Recognition Unit (DSRU).

1 - INTRODUCTION
All the developments carry out by METRAVIB RDS to assess subjective human perception from objective physical measurement are based on a systematic and generic methodology. It allows to find a model of the links between measurements of various sensors and the come back of many experiences acquired by "experts" (acousticians, ergonoms, human sciences experts, ...).
The developed strategy is built on the following steps:

- Over instrumentation of the studied phenomena: a significant number of sensors (chosen according rules of "good sense") are used and associated to various preprocessing (means, RMS, or more complex), providing a large set of signals;
- First step: data reduction based on cross-correlation and signal to noise ratio;
- Second step: data reduction (or data fusion) based on statistical correlation with the studied phenomena.; only the relevant inputs are kept in a reasonable number (compatible with real-time processing) for model identification;
- Model identification: pattern recognition algorithms are exploited to assess the model able to link the physical measurements with the subjective data coming from human experts.

In other words, a supervised learning phase is completed on adequate algorithms like multivariate mean square approach (COMBUSTIOMETRE*) up to Neural Networks (DSRU**), that guarantee flexibility and robustness.

2 - STRATEGY
The general strategy follows a recognition procedure finalised from a supervised learning process with the three stages:

1. Data information (objective measurements and subjective human perception) for several configuration of the studied phenomena are simultaneously collected from all the sensors. Then all these data are pre-processed (filtering to cancel noise). Two kinds of data base are constituted: the learning set, used to maximise the correlation with the parallel human subjective evaluation process to match, and the generalisation set, used to validate the system accuracy and robustness.

2. From temporal, frequency and time-frequency domain analysis, significant parameters are extracted: this is the key phase of data reduction resulting of signal processing. Feature extraction is performed by computing several parameters (first, second, third and fourth order moment) for several assessment situation with a good contrast of subjective human perception. At the beginning we did not fix any kind of constraints and then we selected relevant parameters according rules of correlation with the parallel human evaluation.

3. Decisional phase is applied to the extracted parameters in order to learn the decisional rule during the training phase and to apply this decisional rule during the generalisation phase. For the decisional phase, we either use a multilinear approach [1] (Least Mean Square), either a Bayes rule [2] and more often a neural network [3] that guaranteed flexibility and robustness.

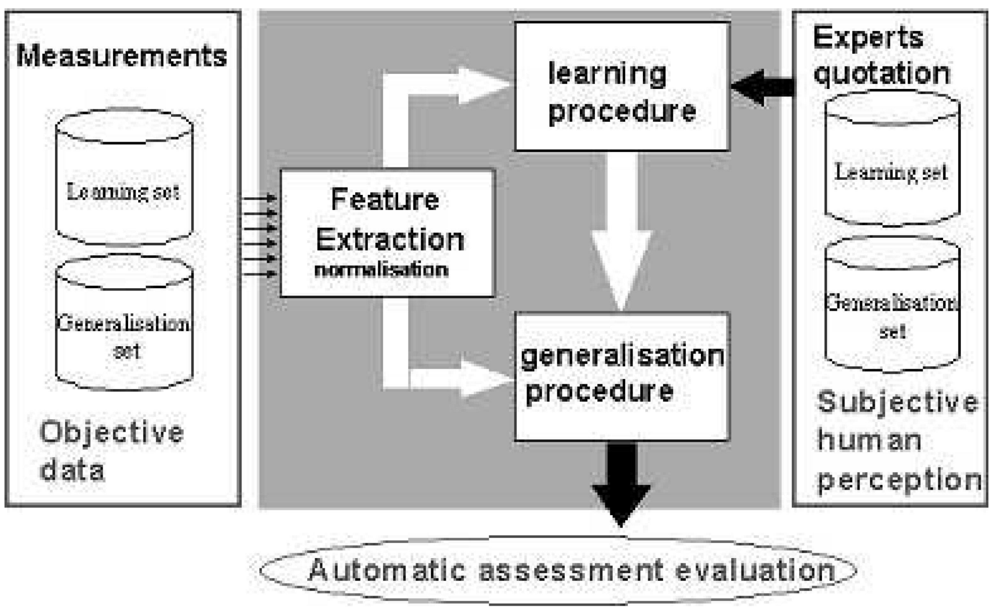

Figure 1: A supervised learning process as general strategy.

3 - DATA REDUCTION

From a great among of sensors and of parameters fixed by rules of "good sens" we perform the selection of the best relevant by using a data discriminant analysis [1].
So the selection of relevant sensors is ensured according rule of signal to noise ratio and according the correlation to the human assessment. Then the parameter selection is ensured by data analysis on the covariance matrix composed by all components of the original data parameters normalised to ovoid scale factor problem. The amplitude of extra-diagonal elements indicates the degree of correlation ρ_{ik} between the parameters i and k. The degrees of mutual dependence between each parameter and/or each sensor, is compute by the Principal Coordinate Analysis. The parameters and sensors are then selected by using the Mahalanobis distance [1] that gives a discriminant power associated to each of the original physical parameters.

4 - TWO INDUSTRIAL DEVELOPMENTS

⇒ The "COMBUSTIOMETRE" has been developed and its principle has been validated in several contracts with PSA in order to perform an objective quotation of the engine subjective combustion noise without the necessity to call experts and without the use of a specific listening. One of the main motivation is the annoyance induced by Diesel engines noise for the users and the customers. This process allows the data collection and processing, in the classic context of an engine test room without any specific acoustic quality, and a final quotation of the engine noise combustion, very close to those of the experts, between 0 and 10 (with 0.5 point of precision).

Figure 2: COMBUSTIOMETRE system.

This innovative system is a flexible tool, that may be adapted to any kind of new architecture engine, and it is also a diagnostic tool which allows to access to combustion quality for a given kind of injection fuel.

⇒ The DSRU (Driving Situation Recognition Unit) is a system aiming at recognising a certain driving situation from dynamic sensors information for a better automotive safety. The embedded system continuously acquired dynamics data on the vehicle and gives in real time the driver's availability. It relates to a new products family globally aiming at "subjective" assessment of continuously evolving situations, from automatic systems supporting (or progressively replacing) human experts assessment in order to evaluate the driver load (attentional workload of the driver) from the driver's actions and his environment. It follows a recognition procedure finalised with a supervised learning phase which awards to the system all flexibility and opening.

5 - CONCLUSION

From many industrial realisations, we have acquired an experience in the way to build a model and a system of the relationship between objective measurements (from physical sensors) and subjective human perception (experts evaluation). These realisations are founded on a generic strategy illustrated by the COMBUSTIOMETRE and the DSRU. They shows results coming from real time application on vehicle that are very close to the experts quotations and are very convincing.

ACKNOWLEDGEMENTS

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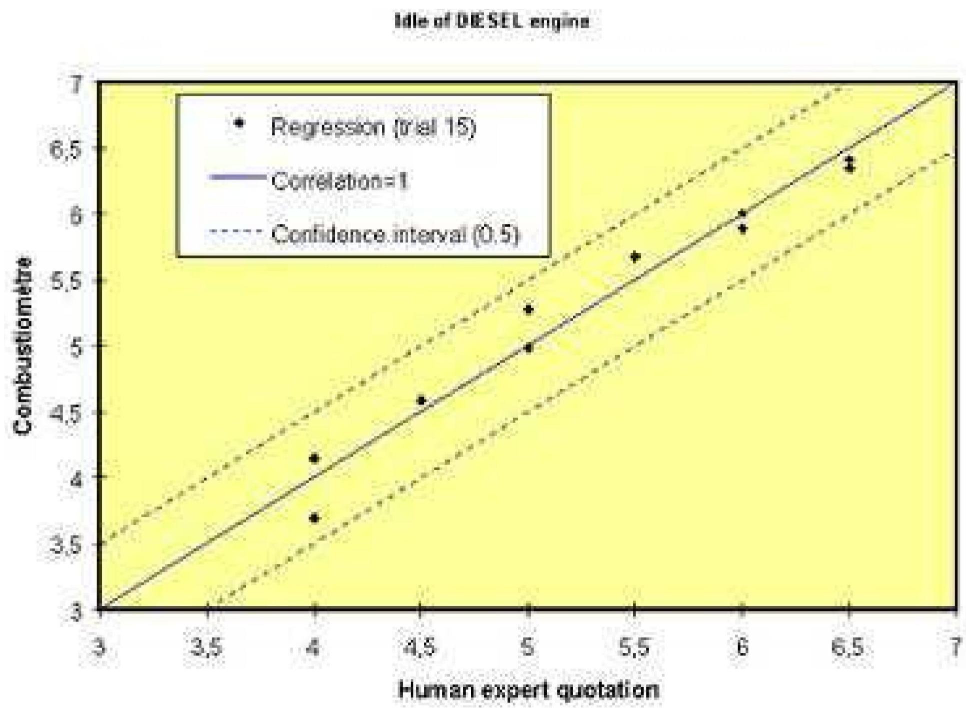

Figure 3: Typical COMBUSTIOMETRE result.

Figure 4: The DSRU system.