A new interactive NVH Vehicle Simulator, what data is required ?

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Introduction

An NVH Vehicle Simulator provides interactivity and context to the traditional NVH evaluation process [1]. The realistic driving environment due to the visuals, vibration and vehicle controls (steering wheel, throttle, gears etc) means assessors, even non NVH-experts, feel much more confident and answer far more consistently about NVH quality [2]. With an NVH Simulator it is also possible to „drive“ a virtual vehicle before a physical prototype has been built. To achieve a high level of accuracy in such a model, it is essential to have good quality data covering the full driving envelope. Application examples of preparation and validation of data are presented.

Implementation of an NVH Simulator

An **NVH Simulator** can accurately recreate the noise and vibration of a vehicle in a user interactive environment. Two main varieties exist. **Desktop NVH Simulator** is a complete system for use in an office environment, enabling the user to experience the sounds of vehicle while “driving” through a virtual scenario shown on a desktop monitor. A **Full Vehicle NVH Simulator** where the user decides what vehicle is to be used, and whether vibration needs to be added to various parts of the vehicle (for example, to the seat, the pedals, the steering wheel). The complete vehicle is situated in front of a projection screen on which a virtual visual scenario is projected.

A car is represented in the NVH Simulator by a hierarchical model, which contains the contributions of all the physical sources that can be heard inside the car when it is operated over its full driving envelope. The model can be used to understand NVH problems, to develop high-level and cascaded source targets [3], and to evaluate individual contributions in a realistic interactive driving environment. The major constituents in the model are: Engine sounds which are dependent on gear and throttle position, Road noise on different road surfaces/speeds, Wind noise as a function of wind speed and direction. Typical secondary sounds in the model are: Squeaks and rattles, Discrete sounds which are only apparent at specific driving conditions such as gear whine, Event sounds such as audible warnings, Ancillary sounds e.g. air conditioning, car audio. This paper describes an effective strategy for measuring the major contributors and including them in the model. As well as the NVH data, the car simulation requires a performance model, which is a parametric representation of its driving dynamics defining the relationship between the instantaneous position of the controls (throttle, brake, gear), the vehicle’s road speed and engine rpm.

The performance model is also usually derived from on-road measurements. Each NVH component in the model is represented by one or more sound objects containing the data together with the rules that determine how the sounds will be synthesized in real time based on values from the performance model. For example, the total engine component needs two sound objects: a set of phase-aligned engine orders to represent the harmonics and a set of masking spectra to represent the broad band contributions. The orders are continuously mapped from the RPM domain to the time domain based on the instantaneous rpm value, whilst the masking sound is a blend of the two random waveforms which are closest to the instantaneous road speed from the performance model.

Fig.1: Desktop NVH Simulator

For a full NVH Simulator model, in which all sources are decomposed to the contribution level, this could result in a very large task and could generate a model which would be too large to be used in real-time. However, an adequate simulator model can contain significantly less data than might first appear necessary without significantly limiting its applicability.

Whole Vehicle Level

Here, the data preparation task is simply to separate on-road recordings into those harmonic and broadband contributions which are proportional to engine speed from those which are related to vehicle speed over the full driving envelope. Two alternatives are the detailed- and the minimum model.

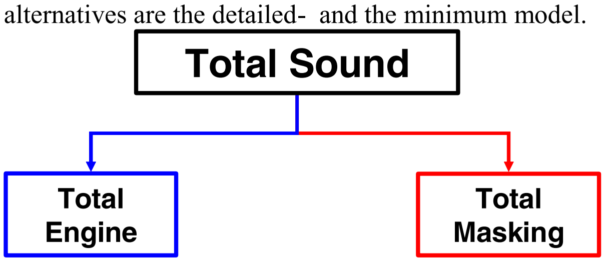

Fig.2: Whole Vehicle Level

Detailed model for Whole Vehicle Level

For Engine Harmonics, the driving conditions are run-ups in each gear at every 20% load including overrun in 2 gears at 0% and 20% load. The recording details are, 34 tests in all with 7 recording channels (binaural sound, engine tacho (2), wheel RPM, throttle, clutch pedal).

For Total Engine Masking, the driving conditions are constant speed in neutral or under load (typical at 20 different speeds). The recording details are, 20 tests in all with 4 recording channels (binaural sound, engine tacho, throttle pedal position).

For Total Road Masking, the driving conditions are Constant speed test every 20 km/h from 0 to 180 km/h on 2 road surfaces. The recording details are 31 tests in all with 4 recording channels (binaural sound, engine tacho, wheel RPM). The time to record and prepare the data would be about 3 days per car. As in any modeling process, it is essential to perform proper validation over a range of operating conditions, usually done both subjectively and objectively.

Minimum model for Whole Vehicle Level

To understand or set targets for powertrain Sound Quality under full throttle conditions, it is not necessary to have very accurate masking sounds, provided that they are reasonably representative. Even in this simple example the ability for the assessor to use the throttle and brake to understand the sound interactively rather than just listening to a pre-recorded sound is extremely beneficial not only because it significantly increases confidence in making the correct judgement but also reduces the time to complete the task. For Engine Harmonics, the driving conditions are 2nd or 3rd gear Wide Open Throttle acceleration. For Total road masking (Road/Wind/Tyre), the driving conditions are Overrun in a gear covering the speed range of interest on two road surfaces. The recording details are 2 tests in all with 4 recording channels (binaural sound, engine tacho, wheel RPM). The time to record and prepare data would be about ½ day per car.

Source Level

The same sound objects can also simulate the individual sources provided that the signature of each source, and the synchronization relationships between sources, can be accurately obtained from operating measurements on a car. The most efficient strategy is to use the correct number and location of transducers and a complete set of operating conditions, together with a robust data processing method which can be easily and reliably automated.

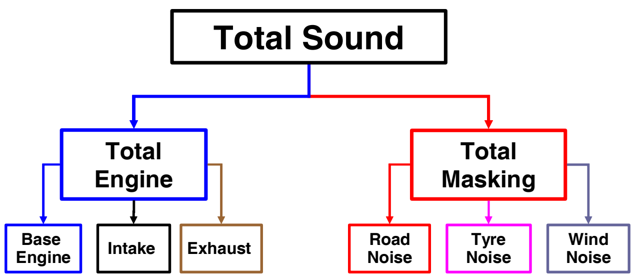

Fig.3: Source Level

The total masking can be decomposed by applying conventional Multiple Input Coherence Analysis (MICA) techniques [4] into simulator sound objects representing the individual sources: front wheel structure borne (road noise), rear wheel structure borne (road noise), front wheel air-borne (tyre noise), rear wheel air-borne (tyre noise), total wind noise. A standard set of measurement locations can be used in almost every situation without the need of pre-tests or specialist knowledge. This means that a universal test procedure can be written to cover not only transducer selection/ mounting and operating test conditions but also the method of processing the data and validating the results.

Normally two surfaces (one smooth, one coarse) are sufficient to define the rolling noise behaviour of a car. A complete characterisation into individual sources, including fitting instrumentation, recording on the road and processing the data into sets of complex spectra ready for free-driving in the NVH Simulator takes typically less than 5 days. One significant benefit of the MICA approach is that it produces independent estimates of the contribution at each level in the hierarchical model. This means that the accuracy of the decomposition can be easily assessed subjectively at all speeds by toggling between the total masking measured on the road and the sum of the five separate sources recorded whilst driving in the simulator. If greater accuracy is required, a more complicated analysis can be performed which takes into account the phase between the coherent energy at each source rather than relying on them being statistically independent which is the underlying assumption in the simple multiple coherence.

Conclusion

An NVH Simulator can improve the effectiveness of the NVH process, by engaging more people and achieving more consistent results with less effort overall than with traditional approaches. Efficient methods for building and validating simulator models have been described which suggest that with minimal extra effort, one can gain the benefits of evaluation of NVH data by free driving in the simulator.

References

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