An On-Board Sound Intensity Data Acquisition System

Muhammed Abdalla, Daniel Cardosi, Aurojit Chakraborty, Joseph Lucatorto, and Javier González Santamaría

Abstract— There is an ever-growing body of evidence around the negative effects of noise pollution, including declines in local wildlife populations near major roadways as well as possible links to health issues such as tinnitus, hearing loss, and heart disease. Automobile traffic is a major driver of noise pollution, yet current research tools often require outdated and cumbersome programs. The software to be developed, requested by the U.S. Department of Transportation's Volpe Center, aims to ease the implementation and scalability of road-acoustics research by interfacing with an external microphone array to perform fully automated measurements of tire-pavement noise via the On-Board Sound Intensity (OBSI) method.

Index Terms— Audio input/output, Hardware/software interfaces, Software/Software Engineering, Sound and Music Computing

1 The Need for This Project

When designing and building cars and roads, many variables must be considered to maximize their harmony not only with drivers but also with the environment and society, noise production being one of these variables. Given that tire-pavement noise dominates in roadway noise at speeds above 30 miles per hour [1] and increases logarithmically with increasing speed [2], on-board sound intensity is an especially useful measurement, as it corresponds to the energy generated at the interface of a vehicle's tire and the pavement beneath it and thus correlates with a vehicle's contribution to roadway noise. Access to a reliable system for this form of measurement may aid in the creation of design constraints for automobile manufacturers and traffic engineers alike, with the eventual goal of quieter traffic.

Organizations such as the Volpe Center adhere to an existing methodological standard for road-acoustics research, known as the On-Board Sound Intensity (OBSI) method and detailed in AASHTO TP 76-10 [3]. This standard defines the entire measurement procedure, including specific numerical data, necessary calculations, and the configuration of all involved hardware. Per Fig. 1 below, sound-pressure data is collected using two pairs of specialized probes in a standardized array configuration, and a single measurement trial proceeds as follows: over a user-prescribed duration of time, the probes feed acoustic data to a laptop in the vehicle as it drives. The current project consists in the development of a software program to be used in the collection and analysis of such measurements.

The software currently used by Volpe to gather OBSI data is outdated: it has a cumbersome interface, only functions on legacy operating systems, and has extremely limited sensor compatibility, leading to increased costs for researchers. Our team's goal is to create a brand new software package that will adhere completely to the AASHTO-standardized process for OBSI measurements. This new software package will collect the same data as the Volpe Center's current software, with the added benefits of greater hardware flexibility, easy distribution, no overhead for license fees, a user-friendly GUI, and access to the source code.

2 Problem Statement and Deliverables

2.1 Statement

Volpe is currently using outdated and unwieldy OBSI-measurement software. Consequently, there is a need to develop an updated and more manageable program. As AdRem Software explains, "outdated software can also disrupt employee workflow or fail to work with other (duly updated) software" [4]. Such is the case here; the lack of access to modern software creates inefficiencies across all stages of the research process, from cumbersome trialing to prohibitive hardware restrictions, yet purchasing new proprietary software can incur expensive, renewable license fees, which can be quite expensive. Our program will provide the Volpe Center with a solution that avoids such adverse consequences.

2.2 Product to be Delivered

The product to be delivered is a LabVIEW-based testing program, in two forms: the first is a standard .exe executable, and the second an editable VI file. We will be using LabVIEW version 2017 and its associated libraries. The

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program will have a user-friendly graphical user interface, and it will be designed to work exclusively with a quad-probe microphone array, per AASHTO TP 76-10. The program will allow the user to calibrate the experimental probes individually, to set a trial time, and to initiate data collection. After data collection, the program will decompose the data into one-third-octave frequency bands with center frequencies ranging from 250 to 5000 Hz and thereafter calculate a variety of acoustical statistics relevant to OBSI evaluation. Finally, the program will allow the user to easily export both processed and unprocessed data to a desired readable format such as a .csv file.

3 Visualization

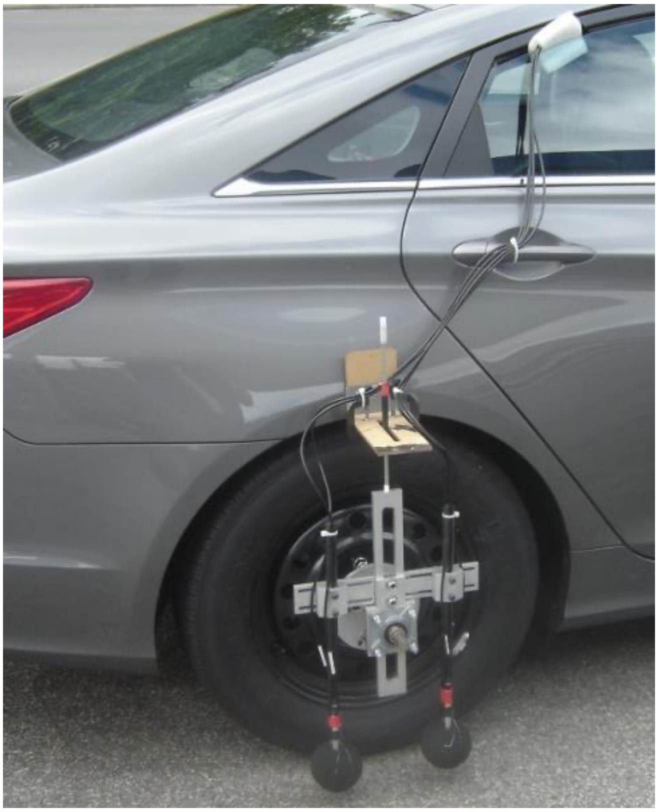

Fig. 1. OBSI probe configuration: each of the two probes consists of a pair of microphones.

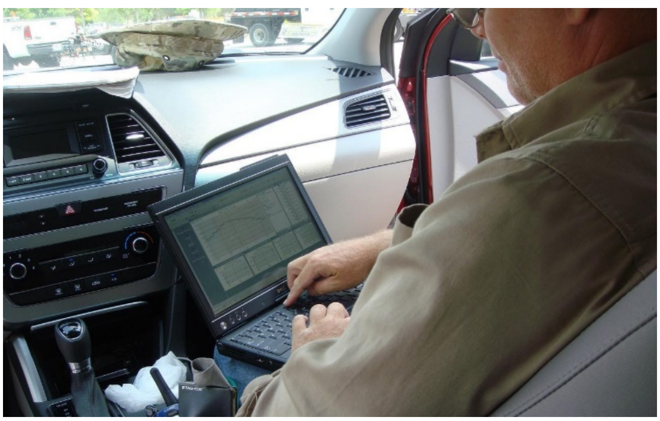

Fig. 2. Example of OBSI data collection software, provided by Volpe.

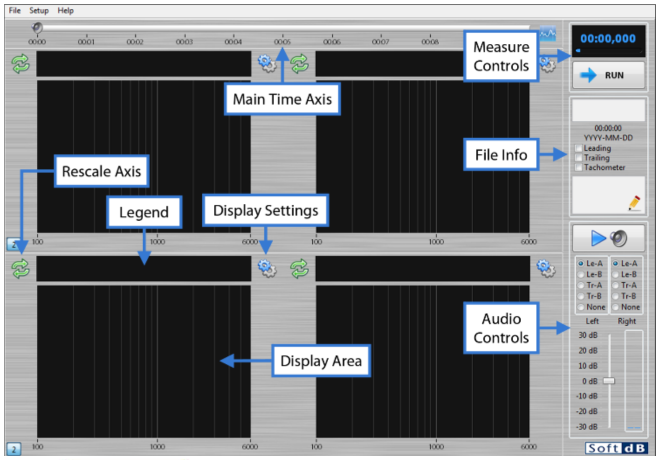

Fig. 3. Example of an OBSI-software user interface, taken from Soft dB's OBSI program.

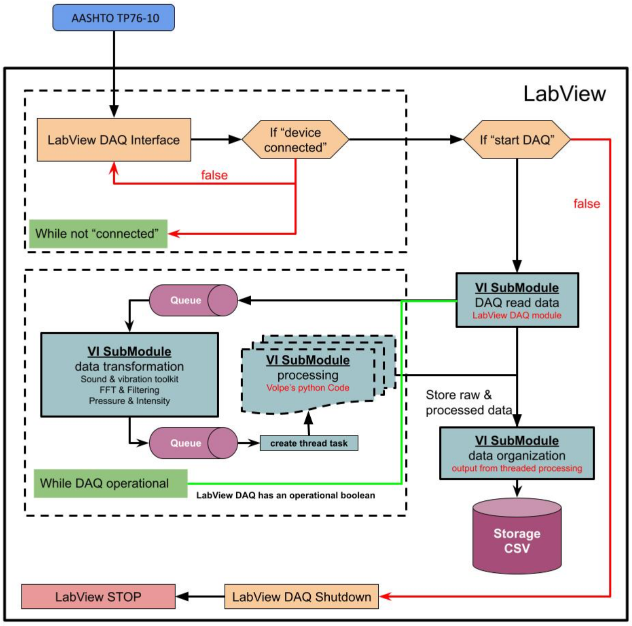

Fig. 4. Schematized diagram of program architecture.

4 Competing Technologies

SoftdB OBSI is the only commercial OBSI measurement program that is both AASHTO TP 76-10 compliant and widely adopted [4]. The software accommodates measurements utilizing both single and dual-probe configurations and is able to calculate sound intensity, sound pressure, PI indices, and inter-microphone coherence [5]. Also supported are ⅓-octave decomposition, amplitude and phase calibration, spectral weighting, variable spectrum ranges, variable microphone spacing, and selection between instantaneous and time-averaged data. The interface includes display types for both numerical results and frequency-domain plots.

There exists a variety of more general programs that may be adapted for OBSI measurements, but such solutions are notably limited by the absence of post-processing tools required by the AASHTO (TP 76-10) method: Room EQ Wizard [6] and Dirac Live [7], for example, both targeted at digital room correction, support multi-input capture as well as ⅓-octave smoothing but do not include automated systems for sound intensity calculation and summation across bands, microphones, and probes.

Though our software will gather the same data as these programs and thus does not surpass them in the domain of functionality or reliability, the development of our program under the specific requests and requirements of the Volpe Center will ensure its compatibility with their existing hardware and allow for a more convenient transition from their current software.

5 Engineering Requirements

5.1 Software

The program will be developed in LabVIEW 2017, in conjunction with the Application Builder Package and the Sound and Vibrations Toolkit. The Volpe Center has provided a hierarchical list of features and specifications, described below and ordered by priority.

1. The user should be able to individually calibrate the four microphones using sensitivity-parameter inputs with a precision of 1/10 mV/Pa.
2. Trials should be manually triggered, and the program should allow trial length to be pre-specified by the user, ranging from 3 to 60 seconds with a precision of 1/10 seconds.
3. On each trial, sound pressure level data should be collected for all four microphones in one-third-octave bands, with center frequencies from 250 to 5000 Hz, with a precision of 1/10 dB. Coherence data between the microphones in each probe should be computed as well, separately for each band, with a precision of 1/10 (unitless).
4. The program should use the acquired single-microphone sound pressure level data to calculate the corresponding single-probe sound intensity levels, both individually for each one-third-octave band and as a logarithmic sum of all single-band intensities. Each of these values should have a precision of 1/10 dB.
5. The computed single-probe sound-intensity-level data should be used to compute the corresponding overall data, consisting of the logarithmic average of the two single-probe intensity levels for each one-third-octave band as well as the logarithmic sum of all logarithmic averages, all computed values again having a precision of 1/10 dB.
6. The program should save all measured and computed data for each trials and store this data across multiple measurement trials.
7. The user should be able to compile and export stored multi-trial data to a human readable format (CSV is preferred), and files should be named by date and time.

5.2 Hardware

As mentioned above, the OBSI probe-array configuration is prescribed by the AASHTO TP 76-10 standard, which will serve both as a design constraint and as a testing mechanism. Designing our program to be hardware-flexible is ultimately an issue not of the hardware itself but rather of our program's architecture and the libraries we employ. As far as system requirements are concerned, labVIEW 2017, compatibility with which the Volpe Center has specifically requested in our program, supports machines running Windows 7, Windows 8.1, and Windows 10. The program will not be particularly resource intensive and as such, computer hardware specifications are highly unlikely to pose any limitations.

6 Acknowledgments

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