Teaching Acoustics Using Smartphones

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1 Introduction

Almost an infinity of smartphone applications exist. Some of them can be related to acoustics and its teaching or be used to encourage experiential learning. This communication presents some possible applications. In particular, three hands-on exercises that are used in an undergraduate course 'Acoustics and noise control' at Université de Sherbrooke (UdeS) are presented.

2 Short overview of acoustics teaching or research approaches using smartphones

Since reviewing all available apps for acoustics and vibration measurement is beyond the scope of this communication, only the three apps used at UdeS are briefly introduced.

Apps for noise measurement.

NoiseCapture [1, 2] is a free and open-source Android application. It allows users to measure sound pressure levels, and to display them as a function of time, frequency, or time/frequency. Each measurement is also combined with its GPS track so that the result can be displayed on an interactive map (Figure 1). A calibration section with different methods is also included in this app (direct, relative). This app has been used in science events for education and awareness purposes for environmental noise assessment (general public/secondary/high school level), for research purposes (crowdsourced noise maps) for indoor noise mapping and finally teacher trainings [1, 2]. *OpeNoise* (Android and iOS) shares the same features as *NoiseCapture*, at the exception of the spatial positioning. Concerning reverberation time measurements, one can cite *APM tool lite* (for Android and iOS). Using hand claps as excitation signals, this app provide reverberation time in octave bands (250 Hz to 4 kHz), and the calculation of additional indicators such as T20, T30 or definition index (D50).

Apps for physics measurements.

Phyphox is an app available for both Android and iOS devices. It provides access to the direct readings from the sensors of your smartphone. Raw data export is straightforward, and remote access to the measuring smartphone from another device is allowed, the measured data can be easily post-processed [3]. Ready-to-play experiments are also available, and any experiment can be built using a web-based design tool on Phyphox website.

3 Smartphones for acoustics teaching.

A series of examples for smartphone-based experiments can be found in the bibliography section of [4] (Refs.[1-8]) and [5] (Refs. [3-11]). These applications include the measurement of the speed of sound in air or in water [4], the characterization of Helmholtz resonators or the measurement of the acoustic response of classrooms [5].

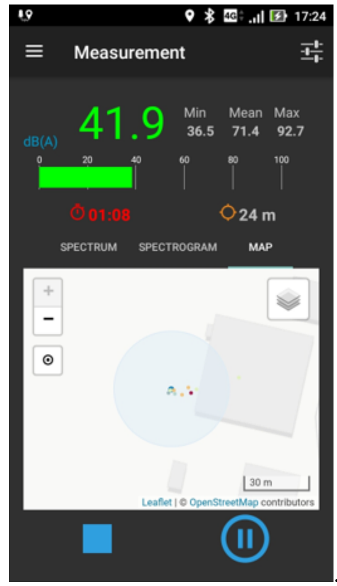

Figure 1: Screen capture of the *NoiseCapture* app with GPS positioning [1].

4 Three examples at UdeS

4.1 Calibrating a smartphone and comparing measured values with other sound level meters.

A first and mandatory example is the calibration of apps to obtain meaningful results. This is also a first step for students to understand the general concept of sensor calibration. Students are asked to calibrate the microphone of their smartphone using a sound source (that can be generated using another smartphone, see Figure 2). The calibration is done by comparison with measurements made using two Class 2 sonometers with digital and needle displays, respectively (Figure 2). Students are asked to make sound pressure level (SPL) measurements for various source types or contexts (they have to chose their own examples) and for at least two different SPL meters. They have then to gather all obtained results in a small report, and these results are discussed during the following course. This laboratory helps students to understand the underlying challenges of sound pressure level measurement (calibration, influence of the measurement position, noise type's influence), and to have a clear idea of the usual SPL encountered in real life applications.

4.2 Mapping sound pressure levels on the university campus.

In this participating laboratory, all the students following the course are asked to contribute to a noise map of the main

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Figure 2: Relative calibration of a smartphone with two Class 2 sonometers - A reference sound source is achieved using another smartphone.

campus at UdeS using the *Noisecapture* app. Between two consecutive courses (one week), the students are asked to use their calibrated smartphones to contribute to a crowd sourced noise map of the campus. This is an occasion for them to be introduced to participating and noise mapping approaches. The results are dicussed during the course.

4.3 Measuring vibration levels and extracting significant features.

This lab is meant to help student making the link between vibration measurements and the extraction of features using simple FFT computations. The goal is to retrieve the idling rpm of a vehicle, as depicted in Figure 3 (note that only idling condition is considered to ensure safety). The students are asked to place the smartphone on a car hood, to launch a vibration measurement using *Phyphox* application, and finally to start the vehicle and stop it after approximately 60 seconds. The raw data (Figure 3-2) is then post-processed using Matlab. A value of 797 rpm is finally estimated by multiplying the identified fundamental frequency (13.31 Hz, see Figure 3-3) by a 60 factor to convert it into rpm (car's tachometer indicates 800 rpm).

5 Discussion and perspectives

This communication briefly introduces the possible uses of smartphones in acoustics teaching, including three examples extracted from a series of ten labs using smartphones developed at UdeS. These labs have several advantages including (1) the fact that laboratories can be handled in actual situations with no specific lab room nor specific tools and (2) the fact that the main lab support, a smartphone, is a common resource to all students making it accessible and flexible. The first results extracted from recent surveys indicate that students engagement and experiential learning are improved.

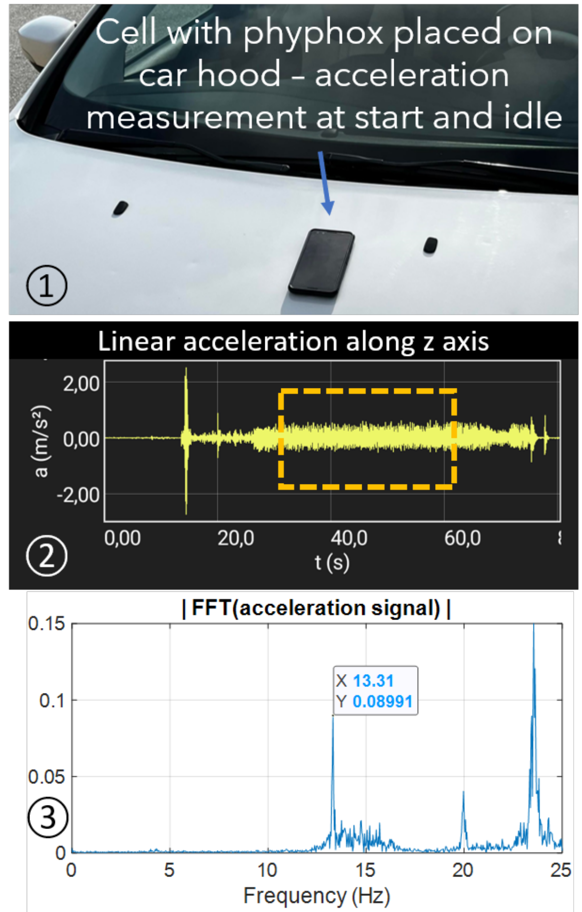

Figure 3: Estimation of the idling rpm of a car - (1) Vibration measurement on the car hood - (2) Raw acceleration time signal (the chosen idling time window is indicated by a dashed orange box) - (3) Computation of the FFT to estimate the engine's fundamental frequency of rotation.

The perspectives include (1) the continuous improvement of acoustics-related labs, and (2) the use of smartphones in a thermal course using infrared smart cameras.

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