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Publication date
2018

Document Version
Final published version

Published in
Proceedings of the 12th International Symposium on Tools and Methods of Competitive Engineering (TMCE 2018)

Citation (APA)
Bazilinskyy, P., van der Aa, A., Schoustra, M., Spruit, J., Staats, L., van der Vlist, K. J., & de Winter, J. (2018). An auditory dataset of passing vehicles recorded with a smartphone. In I. Horváth, & J. P. Suárez (Eds.), *Proceedings of the 12th International Symposium on Tools and Methods of Competitive Engineering (TMCE 2018)* (pp. 417-422). Delft University of Technology.

Proceedings of TMCE 2018, 7-11 May, 2018, Las Palmas de Gran Canaria, Spain, edited by I. Horváth and J.P. Suárez

AN AUDITORY DATASET OF PASSING VEHICLES RECORDED WITH A SMARTPHONE

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ABSTRACT

The increase of smartphones over the past decade has contributed to distraction in traffic. However, smartphones could potentially be turned into an advantage by being able to detect whether a motorized vehicle is passing the smartphone user (e.g., a pedestrian or cyclist). Herein, we present a dataset of audio recordings of passing vehicles, made with a smartphone. Recordings were made of a passing passenger car and a scooter in various conditions (windy weather vs. calm weather, approaching from the front vs. from behind, 1 m, 2 m, and 3 m distance between smartphone and vehicle, vehicle driving with 30 vs. 50 km/h, and smartphone being stationary vs. moving with the cyclist). Data from an 8-microphone array, video recordings, and GPS data of vehicle position and speed are provided as well. Our present dataset may prove useful in the development of mobile apps that detect a passing motorized vehicle, or for transportation research.

KEYWORDS

Traffic, microphone, smartphone, sound analysis, sound processing

1. INTRODUCTION

The number of fatal traffic accidents in high-income countries has decreased over the past decades [12]. In the Netherlands, after the years of decline of the number of road deaths, resulting in 570 road deaths in 2013 and 2014, the number has increased to 621 in 2015 and 629 in 2016 [13]. At the same time, 81% of Dutch people between the age of 18 and 80 years old own a smartphone [9]. Smartphones are now a major cause of distraction in traffic [3], [6], [14]. With the present contribution, we aim to contribute to a solution, where smartphones are turned into a benefit rather than a risk.

Various studies have classified passing vehicles based on the sounds emitted by those vehicles. For example, Meucci et al. [8] described the development of a low-cost microcontroller that can discriminate a siren from other sound sources in traffic. Similarly, Takeuchi et al. [15] developed a filter that can detect a siren from a microphone signal, whereas Fazenda et al. [5] developed a microphone array that can determine the incoming direction of a siren. Averbuch et al. [1] presented an algorithm that can detect vehicles of different types (e.g., car, truck, minibus) by comparing the acoustic signature against a database of acoustic reference signals. Various authors have presented a low-cost microphone array that allows for the computation of traffic characteristics such as [2], [7], [10], [11], [16], [18]. Thus, based on the existing research, it appears to be feasible to extract the presence of nearby vehicles using auditory information.

Previous studies on the usage of sound measurements in traffic have employed microphone arrays. This study focuses on the use of the microphones in a mid-range smartphone. We created a dataset of audio recordings of motorized vehicles passing a stationary or moving smartphone. This way, we aim to contribute towards an application where the microphones in a smartphone are used to detect passing motorized vehicles.

2. MEASUREMENTS

A total of 139 scenarios were recorded, representing a non-crossed combination of condition that were assumed to be representative of typical traffic. Three measurement series were performed on three separate days.

2.1. Measurement Series 1

A mid-range Android smartphone Xiaomi Redmi 2 Pro was mounted on a 30x30x30 cm cubic microphone array, with a microphone on each of the eight corners. The smartphone was mounted on the side of the cube, with the vertical axis of the smartphone parallel to the road. The smartphone had one microphone at the top and one at the bottom. The distance between the two microphones was 13 cm

(Figure 1). A GoPro Hero 4 Silver camera was mounted parallel to the road to record oncoming traffic.

Figure 1 8-microphone array, together with the smartphone on the side and GoPro on top (Measurement Series 1).

A Garmin GPS tracker was mounted on the test vehicles. The test vehicles were a 1996 BMW 328i car and a Vespa LX50 scooter. Both the car and scooter were petrol vehicles. The car and scooter drove past the stationary smartphone, at a speed of either 30 km/h or 50 km/h, and approached the camera from the front or from behind. A total of 30 scenarios were recorded. Weather conditions were windy. The measurement location was a relatively empty public road: Delftweg 172, 3046 NC Rotterdam, the Netherlands.

Video footage of the camera and audio of the smartphone were synchronized using Adobe Premiere Pro software. GPS data and video footage were synchronized using Dashware software.

2.2. Measurement Series 2

In Measurement Series 1, the conditions were windy. Experiment Series 2 was performed in more calm weather conditions. The measurement location was a road past a rowing track: Willem-Alexander Baan, Nely Gambonplein 1, 2761 Zevenhuizen, the Netherlands. A microphone cover (‘dead cat’) was put on the same smartphone as in Measurement Series 1, to reduce wind noise.

The (1) car, (2) scooter, or (3) scooter and car driving after each other drove past the stationary smartphone, at a speed of either 30 km/h or 50 km/h, and approached the camera from the front or from behind. Furthermore, the scooter passed the stationary setup at a distance of approximately 1 m, 2 m, or 3 m from the smartphone. Marks were placed on the road at 1 m, 2 m, and 3 m distance from the smartphone (Fig. 2). A total of 52 scenarios were recorded.

Figure 2 View from the inside of the car while following the scooter. Marks are made on the road using cones and tape. The measurements were conducted on a wind-free day (Measurement Series 2).

2.3. Measurement Series 3

Measurement Series 1 and 2 were performed with a stationary smartphone plus an 8-microphone array. In Measurement Series 3, sounds were recorded of the passing car while the same smartphone as in Measurement Series 1 and 2 moved at speeds of 15 km/h, 20 km/h, or 25 km/h (i.e., typical cycling speeds [17]), without using the microphone array. For these recordings, the camera, smartphone, and GPS tracker were mounted on the bicycle, as can be seen in Figure 3. Again, the smartphone was mounted with its vertical axis oriented parallel to the road. The car drove 30 km/h or 50 km/h, and overtook the cyclist or drove in the opposite direction. In addition to mounting the smartphone on the bicycle, we also included scenarios in which the smartphone was kept loosely in the back pocket of the cyclist’s jacket. This is closer to a real-life scenario where a cyclist could put the smartphone in his/her jacket. As in Measurement Series 2, a microphone cover (‘dead cat’) was put on the smartphone to filter wind noise. A total of 57 scenarios were recorded. The measurement location was the same as in Measurement Series 2.

3. RESULTS

3.1. Dataset

The dataset consists of 139 scenarios. Each scenario comprises a Waveform Audio File Format (.wav) file, in stereo at 48 kHz. Each .wav file is accompanied by a MPEG-4 (.mp4) file showing the same scenario recorded with the GoPro camera, together with GPS recordings of the position and speed of the moving vehicle (see Fig. 4, for screenshot). For Measurement Series 3, the speed of the cyclist is provided in the video file (Fig. 5).

Figure 3 The smartphone with wind cover and GoPro camera mounted above the rear wheel of the bicycle (Measurement Series 3).

Figure 4 Screenshot of a video, with the car passing the stationary microphone setup (Measurement Series 1).

Figure 5 Screenshot of a video, with the car passing the moving cyclist. In this scenario, the smartphone, camera, and GPS tracker were mounted on the bicycle (Measurement Series 3).

Figure 6 shows a spectrogram of one selected scenario of Measurement Series 2. In this scenario, the scooter drove at 50 km/h and passed the stationary smartphone at a distance of 2 m. From this spectrogram, it is relatively easy to detect whether there is a vehicle in the vicinity as compared to background noise, as seen in Figure 6, bottom. In a windy scenario (Fig. 7), or in a scenario with a moving cyclist (Fig. 8), classification between the presence versus absence of a passing vehicle is a harder task. For example, in Figure 7, a car passes the stationary microphone in windy conditions and without wind cover; the power peak is still evident when the vehicle passes, but is less so than in Figure 6.

A cross-correlational analysis of the two microphones was performed using a 100 ms moving time window. This technique involves calculating the time difference for which the similarity between the two signals is the highest. The sign reversal that is seen in Figure 9 is due to the vehicle passing the microphones. It can be seen that the direction of the sound source can be reliably identified, already 8 seconds before the vehicle passed (Fig. 9). Given the fact that the speed of sound is approximately 340 m/s, a time difference of 0.4 ms corresponds to the distance of 13 cm between the two microphones of the smartphone. Figure 10 shows the corresponding data from the microphone array. Here, the signal from one selected microphone was cross-correlated with the seven other microphones of the cube.

4. DISCUSSION

We presented a dataset of passing vehicles and scooters in different testing conditions. The measurement data, which are available online, may prove useful for researchers who want to develop algorithms that classify whether or not there is a vehicle near the smartphone. Our results presented in Figures 6–8 suggest that passing vehicles can be distinguished from background noise by using a heuristic of power in the 5–24 kHz range. Furthermore, the direction of approach of the passing vehicle can be inferred from the results of a cross-correlational analysis (Fig. 9).

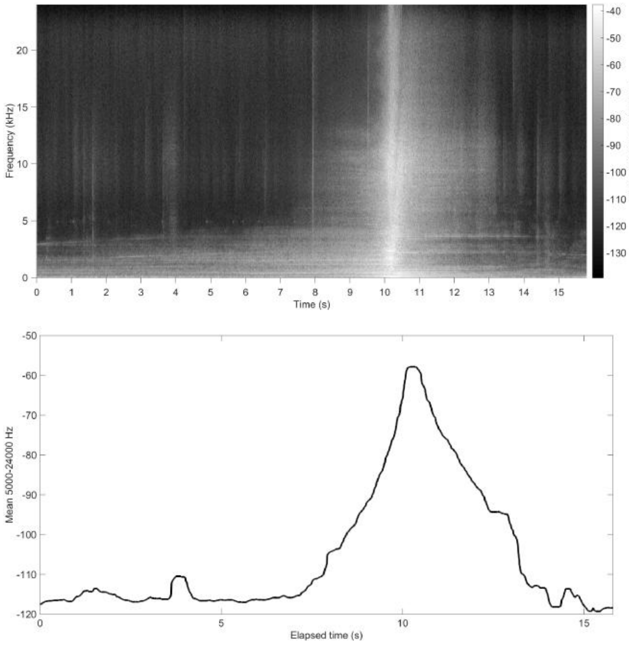

Figure 6 Top = Spectrogram of a car passing with 50 km/h, in a condition without wind and with ‘dead cat’ wind cover (Measurement Series 2). Bottom = sum of the power in the 5–24 kHz range, filtered with a median filter with 0.5 s window.

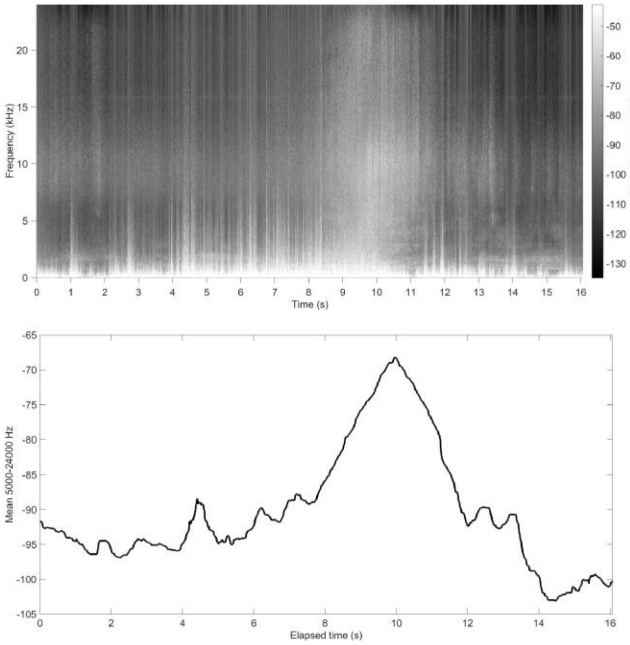

Figure 7 Top = Spectrogram of a car passing with 50/h in windy conditions and without wind cover (Measurement Series 1). Bottom = sum of the power in the 5–24 kHz range, filtered with a median filter with 0.5 s window.

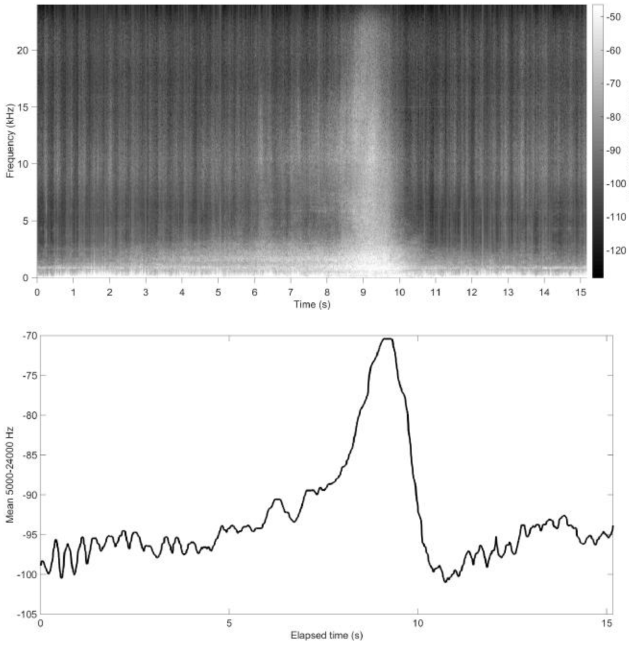

Figure 8 Top = Spectrogram of a car driving 50 km/h and passing a bicycle riding 25 km/h (Measurement Series 3). The smartphone was mounted on the bicycle and surrounded by a ‘dead cat’ wind cover. Note that the cycling cadence can also be inferred from this figure. Bottom = sum of the power in the 5–24 kHz range, filtered with a median filter with 0.5 s window.

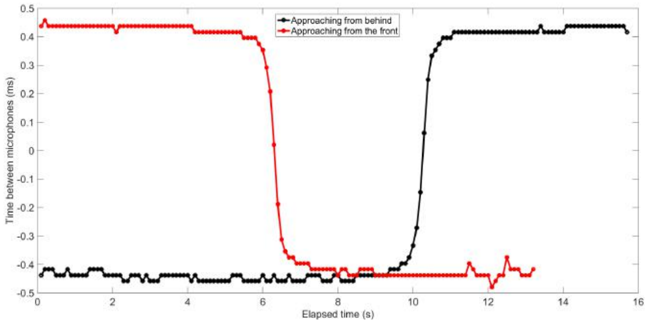

Figure 9 Time difference between the two microphones, estimated using cross-correlation. These ‘approaching from behind’ data correspond to the same scenario as shown in Figure 6 (Measurement Series 2).

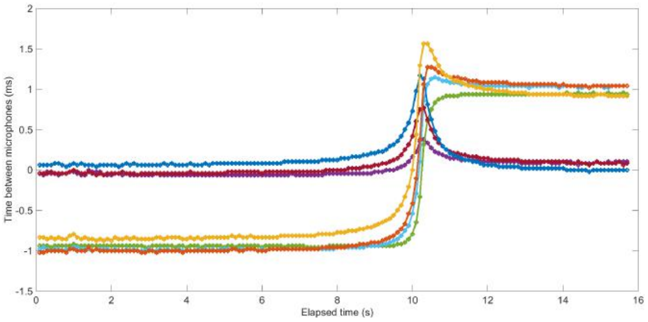

Figure 10 Estimated time difference between 1 microphone and the 7 others of the 8-microphone array. These data correspond to the same scenario as shown in Figure 6 (Measurement Series 2).

Classification algorithms may be valuable in the development of mobile apps. For example, the microphones of a smartphone are currently used in an application called ‘Awareness!’. This headphone app allows users to hear what occurs around them while listening to music. According to the developer, their real-time Digital Sound Processing (DSP) engine analyses the surroundings and feeds important sounds straight to the headphone [4]. If such app would be able to understand whether vehicles are driving nearby, then the music could be dimmed to make the user (e.g., a cyclist) better aware of the passing traffic. With appropriate tuning of the algorithm, the app could possibly be run on a mobile phone placed in a pocket. The cyclist must still be aware of the surroundings, and special care must be taken to avoid problems of over-reliance.

In summary, we expect that the present dataset and supplementary MATLAB script could be put into use for further developing mobile apps that help to improve traffic safety. Our dataset and methods may also prove useful for transportation research. For example, a smartphone could be used to record in a low-cost manner how many vehicles are passing per time unit, and what the time differences are between those vehicles, on a particular road. In future research, the performance of the algorithm may be tested with electric vehicles and in noisy city environments.

The dataset and MATLAB script are available online: http://doi.org/10.4121/uuid:bef54ab8-73ef-42f3-b6b7-54e011737e72

ACKNOWLEDGMENTS

Pavlo Bazilinskyy and Joost de Winter are involved in the Marie Curie ITN: HFAuto (PITN-GA-2013-605817). Joost de Winter is supported by the research programme VIDI with project number TTW 016.Vidi.178.047, which is financed by the Netherlands Organisation for Scientific Research (NWO).

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