The Applications of Vehicle Sound Analysis in Autonomous Vehicles and Noise Pollution

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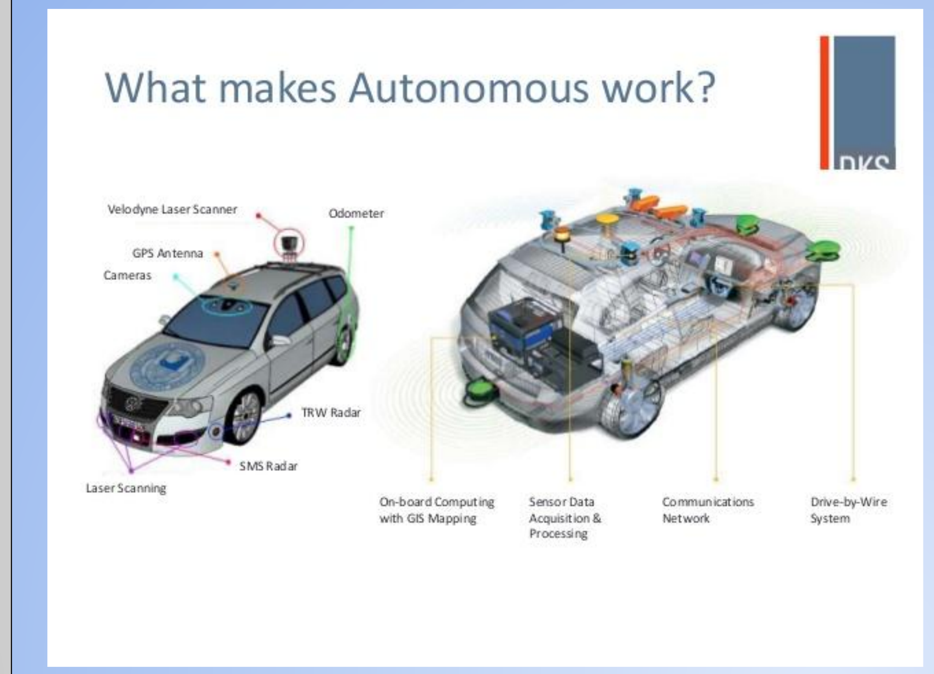
Summary

Audio samples of various electric and fossil fuel burning vehicles were collected in order to see if there were any distinguishing characteristics that could be used to identify vehicles using audio analysis. The audio samples were compared using Fourier Transforms to generate spectrums of frequency and amplitude over a given interval of time.

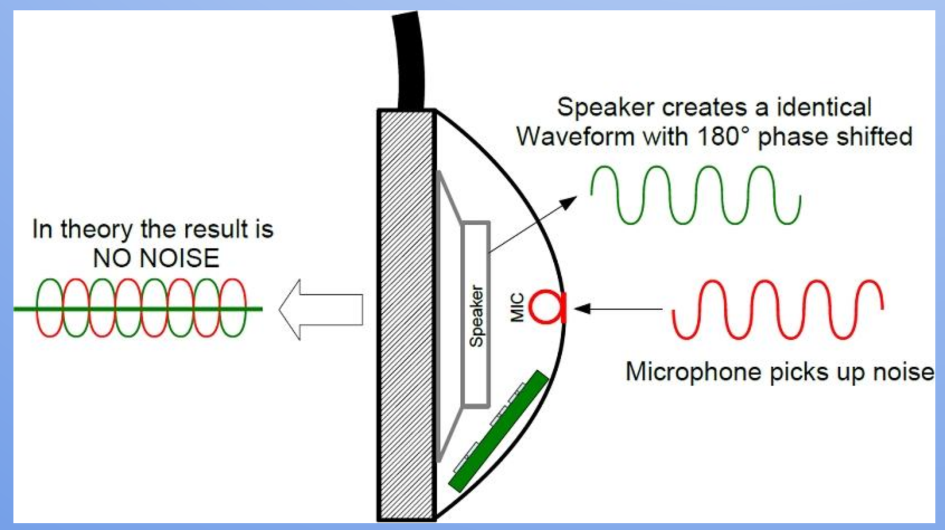
Background and Significance

As of now, it is not uncommon to see Google or Uber's prototype autonomous vehicles cruising through residential and business districts in the Bay Area. With the amount of resources and research that are channeled into the development of this field, we could soon see the creation of the first private self-driving car. However, most autonomous vehicles use image processing algorithms to function properly, a method that can be limited by weather and time of day. As a result, other methods such as sound processing should be used, either in combination with image processing or completely independent of image processing, in order to increase the reliability of autonomous vehicles. To accomplish this, the first step would be to distinguish the natural sounds emitted by vehicles from other sounds.



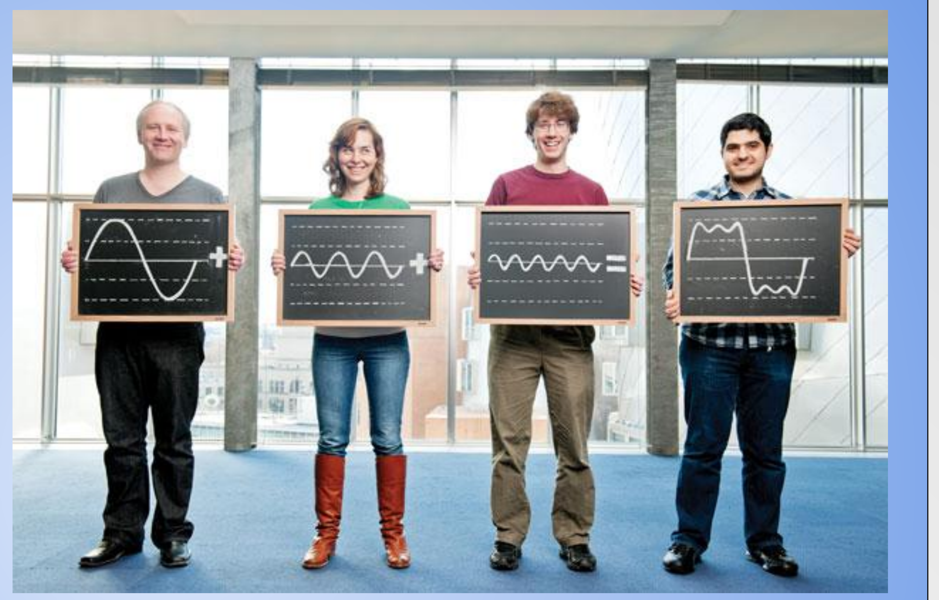
Current implementations of autonomous cars

Another application is noise pollution. Especially in overpopulated cities such as Tokyo and New York, high levels of traffic congestion lead to noise pollution, a phenomenon correlated to multiple health issues such as cardiovascular diseases and stress (Stansfeld, 2016). One way to address noise pollution is to tackle sources that produce sounds in motorized vehicles. Some technologies that are able to cancel noise do so by recognizing the environmental sounds that must be muted, and then emitting frequencies that cancel those noises. This is called active noise control (Elliot, Nelson, 1993), a method that is most commonly seen utilized by sound systems technology companies such as Bose with their noise cancelling headphones.



Fourier Transform

The Fourier Transform simplifies natural, complex sound waves into a summation of sinusoidal functions (Bullard, 2017). This was the main tool used to analyze the audio files of motorized vehicles. The mathematical function is displayed below.



$$f(x) = \Sigma A_n \sin(nx) + \Sigma B_n \cos(nx)$$

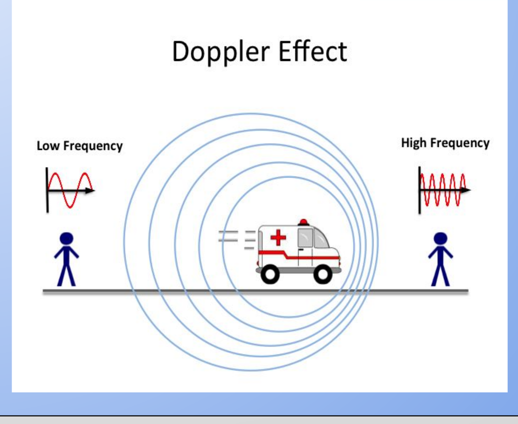
With some calculus, the values of A and B, which compose the amplitudes of specific frequencies, can be found.

Execution

First, sounds of single vehicles driving on the road were recorded. This was done using three vehicles: a Honda 2014 CRV, a Toyota 2008 Camry, and a Ford Focus Electric. Recordings were simultaneously taken using three cell phones: a LG VZ20 using HD Audio Recorder, an Apple iPhone 8, and a Samsung Galaxy 4. The Camry and CRV were individually driven past the recording cell phones at 15, 25, 35, and 45 mph on an isolated street from 5:30 - 6:30 am, in order to ensure that no other vehicles would be present on the road. The wav files were normalized to -1.0 dB, and spectrograms of the recordings were created using the Fourier Transform algorithms of Audacity. These spectrograms were integrated over an 8-15 second time period at the points where the vehicles were approaching and passing the recording cell phones.

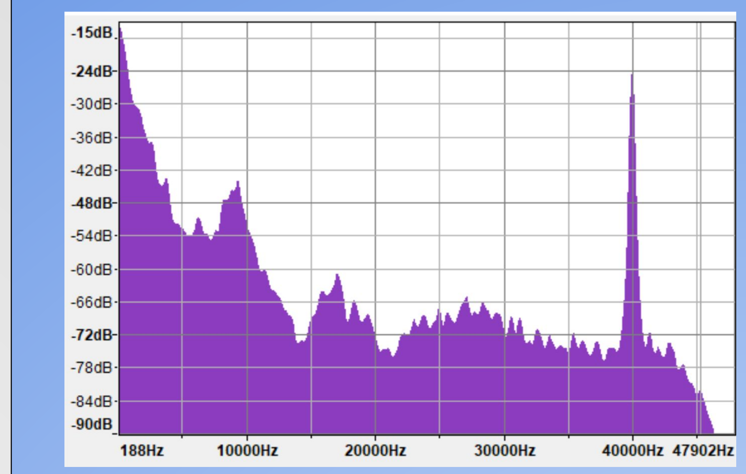
Conclusion

The generated spectrograms for the CRV, Ford, Camry, and classroom activity all covered a wide range of frequencies, and also had similar shapes where the lower frequencies dominated, along with a slight peak at the 8000 - 8500 Hz frequencies. Therefore, it will be difficult to distinguish vehicles from general background noises, as opposed to a singular individual speaking. Further research can involve more complex techniques to distinguish vehicles from background noises, or an entirely different method from sound recognition. Such techniques could involve the use of the Doppler Effect to detect fast moving objects. Furthermore, audio samples of more unique vehicles such as commercial trucks and military units can also be gathered.

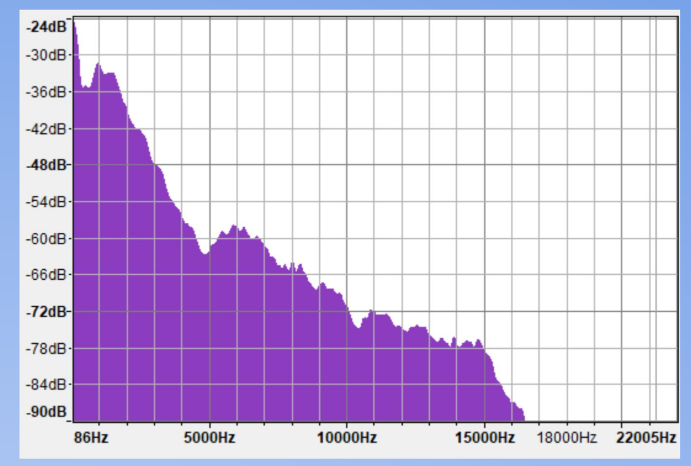


Data and Results

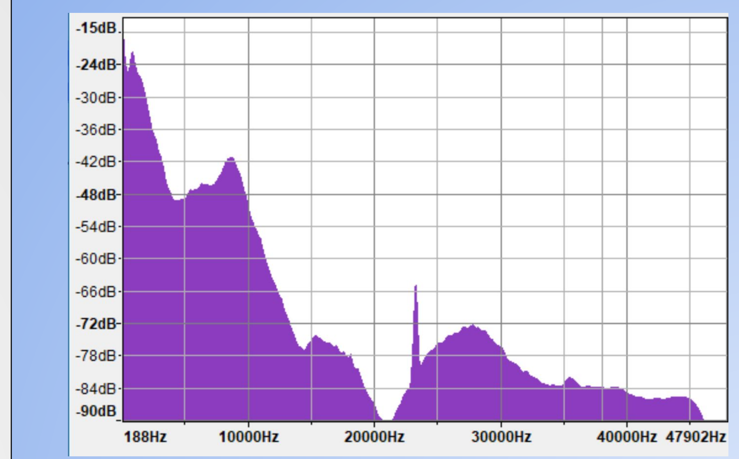
Classroom activity, LG V20



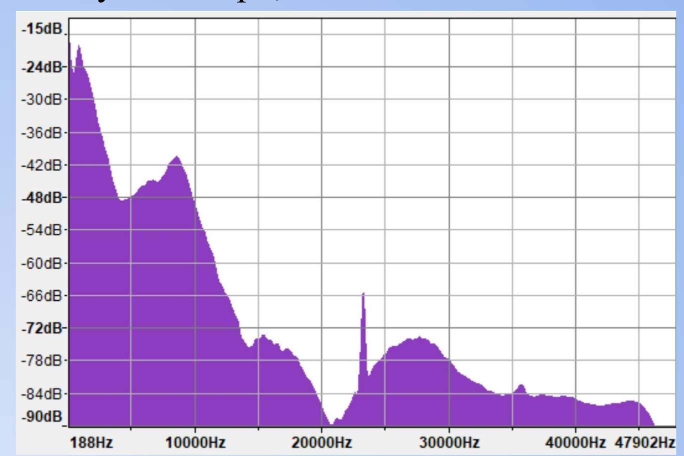
Camry at 45 mph, iPhone 7



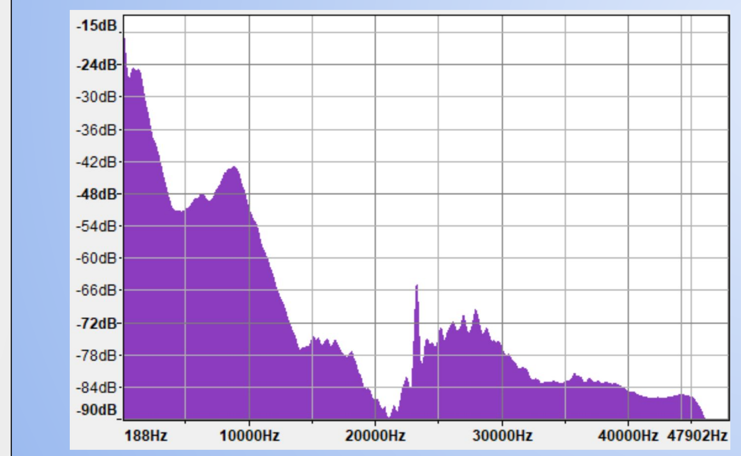
Camry at 35 mph, LG V20



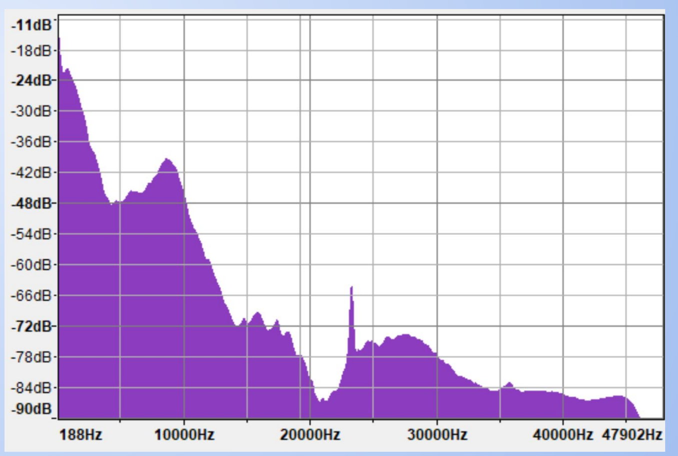
Camry at 45 mph, LG V20



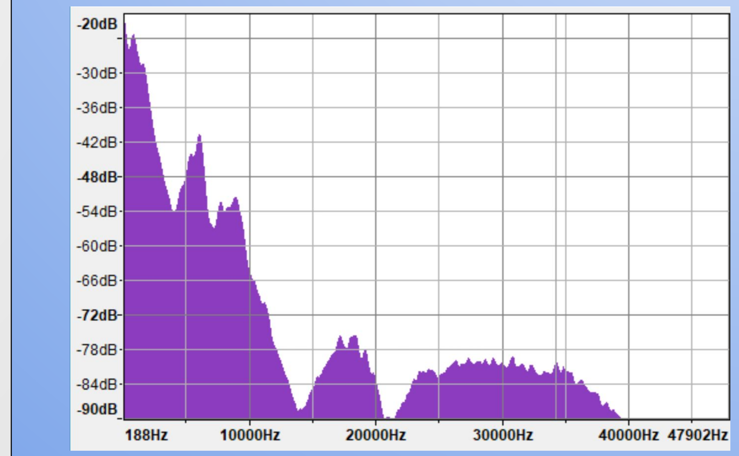
CRV at 35 mph, LG V20



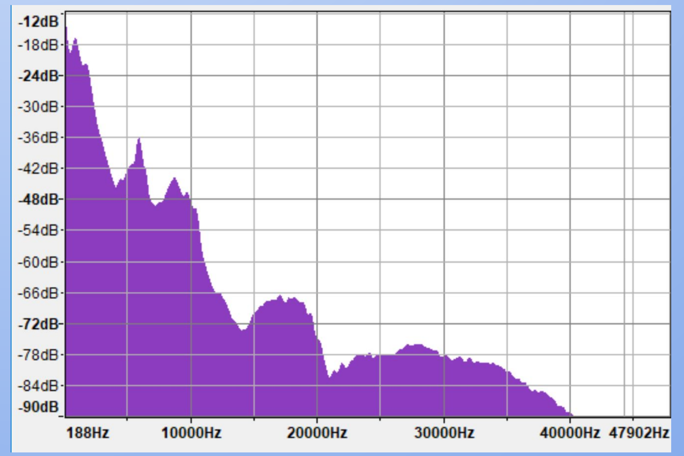
CRV at 45 mph, LG V20



Ford at 35, LG V20



Ford at 45, LG V20



These graphs display frequency on the x-axis in Hz, and sound intensity in dB on the y-axis, for a given time range of 8-15 seconds. While it was assumed that noises generated by humans would not extend over 500Hz, the first graph clearly displays that general background noise contains high frequencies with significant amplitudes, possibly due to the harmonics of the human voice, as well as general percussive sounds such as walking. Therefore, it is not sufficient to detect vehicles by simply looking for frequencies over the human hearing spectrum (20kHz).

Acknowledgements and References

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