Characterization of near-surface geology using correlations of traffic signals recorded on smartphones

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Introduction

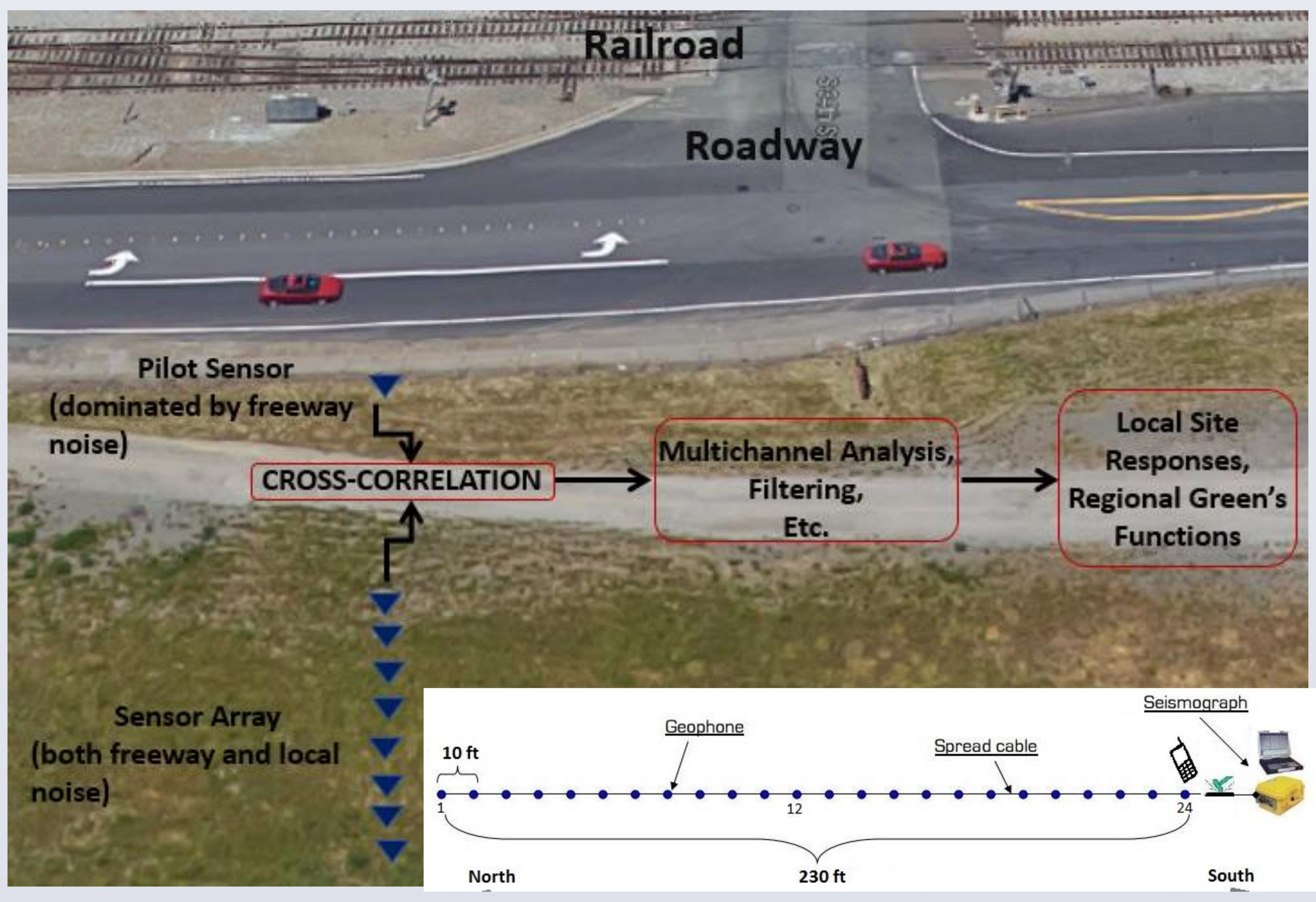
Nowadays, as the communications infrastructure is modernizing more and more, cellular phones are everywhere and relatively affordable. The purpose of this research is to take advantage of their availability to investigate and develop advanced multichannel signal processing and big data analytics to exploit dense arrays of seismic sensors in urban environments. Such arrays will be used to characterize local seismic site response and regional geology at higher frequencies (2-15Hz). The built-in accelerometers of the smartphones will receive and record semi-continuous broadband noise, mainly from roadway or railroad traffic.

The costs of these cellular devices are forecasted to be lower than those of the traditional geophones and their associated technology. Furthermore, the deployment of an array of cellphones is cheaper, less invasive, and less time-consuming than drilling boreholes at a fine scale for the collection of samples to be analyzed later in a lab.

The success of this method will be beneficial to relevant geotechnical applications and oil/gas activity monitoring. Moreover, developing countries such as Haiti, where the resources to develop any type of seismic network are scarce and building quality poses greater risks for damage and safety, can benefit the most from this technology.

Method

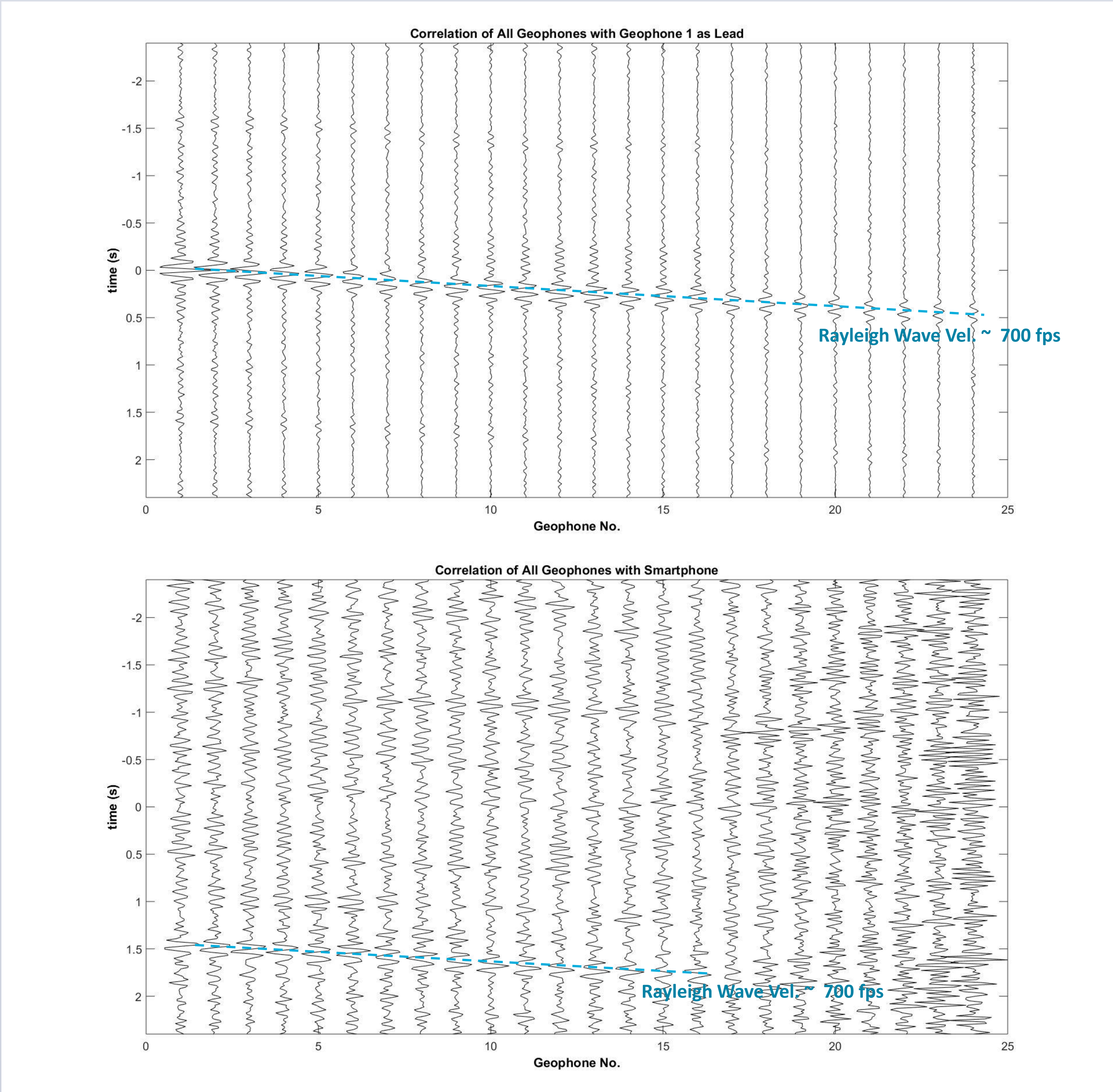
The ultimate goal is to use passive noise in urban areas to characterize local geology using dense arrays of mobile devices as receivers. Active sources such as accelerated weight drops have generally been used to accomplish this task. Instead, we propose to cross-correlate signals obtained from passive sources such as roads and railways. Extensive data acquisition and processing are critical components of this investigation. As a result, a combination of laboratory, field and computational experiments is required.



Technical Approach

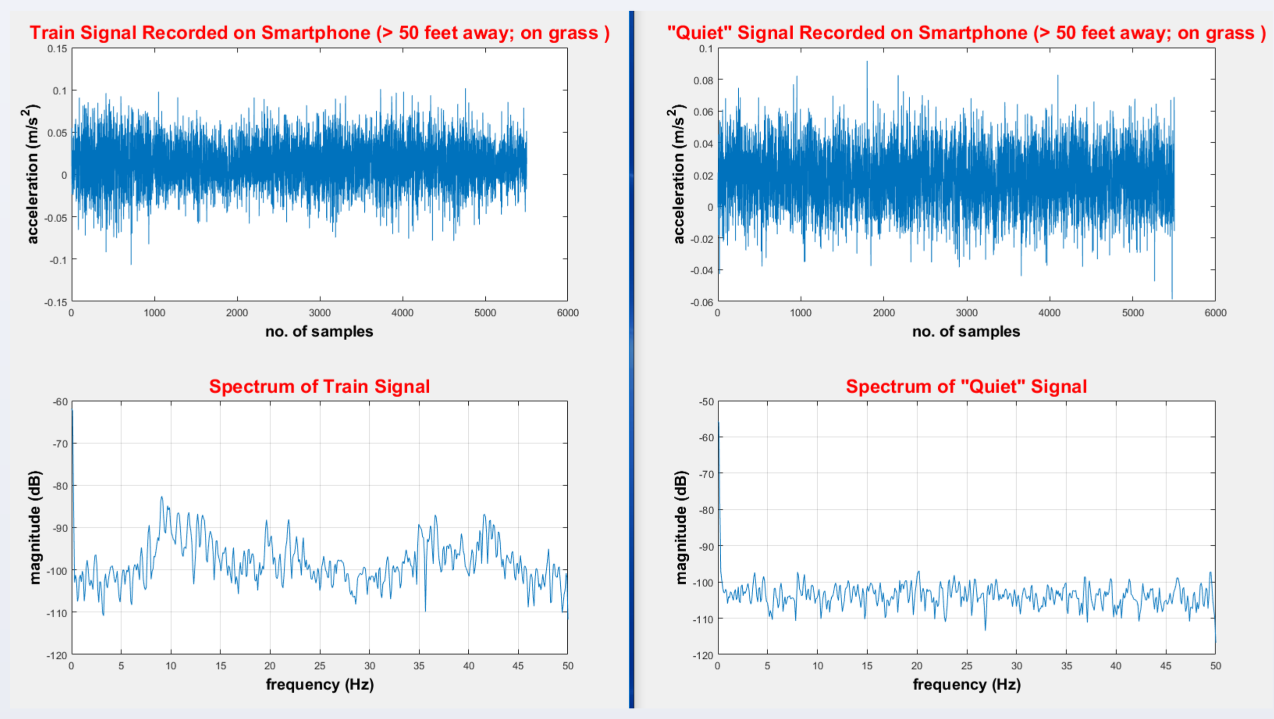
- Model of ambient seismic noise in an urban environment
- Cross-correlation
- Obtaining Green's functions and local site response from cross-correlations

Preliminary Work: cellphone vs. geophone



Feasibility study: more predictable noise source

Although the traffic density on freeways is greater and provides more regional coverage, one of the issues with using freeway noise is that the source function may be variable. Weather-related pavement and variable traffic conditions can affect the nature of the freeway noise source.

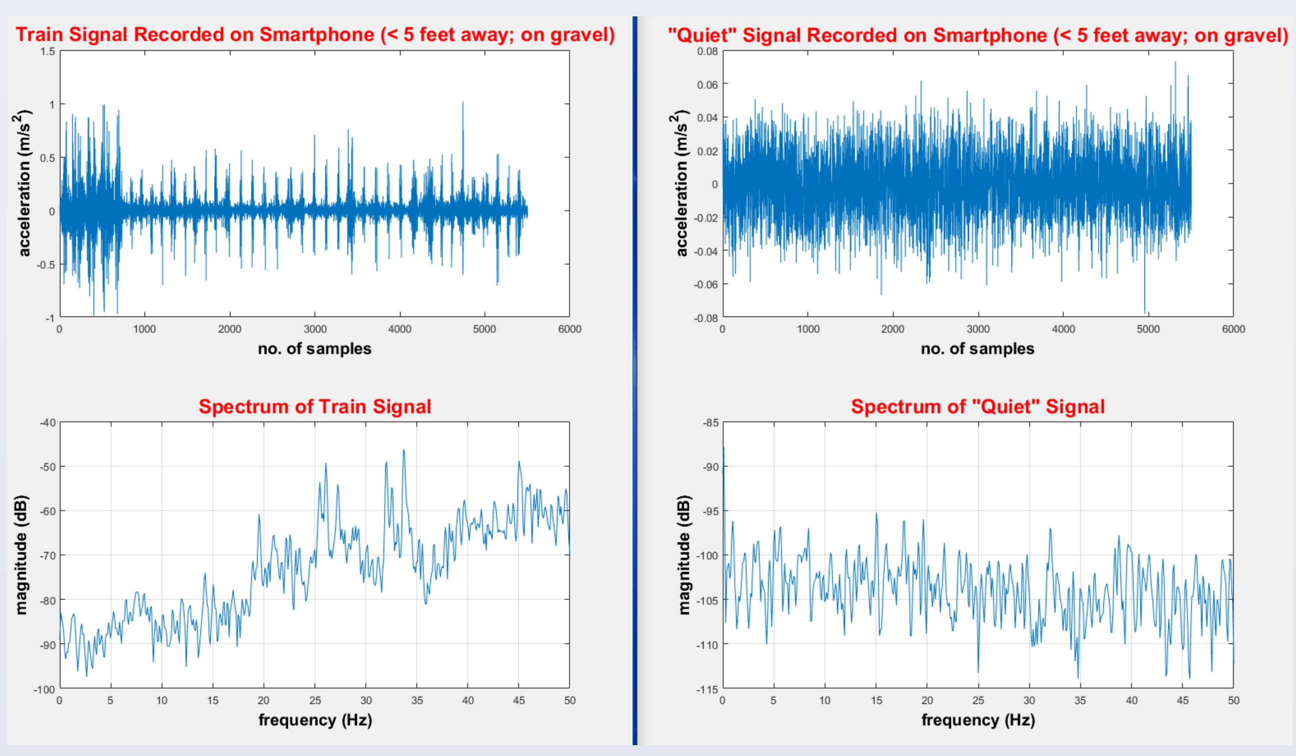


In some areas, trains and/or subway systems, such as AMTRAK, may be a better traffic noise source.

Due to the size of the train, the noise should extend to lower frequencies.

Moreover, the source should be much more repeatable.

Finally, with a known train schedule, raw data time-windows can be prescribed for creating cross-correlations.



Coverage area

The width of the useful corridor will depend on the nature of the coherent signals. Waves traveling from the traffic noise at high frequencies in the near-surface will have a more limited swath of coverage. By contrast, deeper penetrating, longer wavelength refracted arrivals may be detected at much larger distances from the traffic noise.

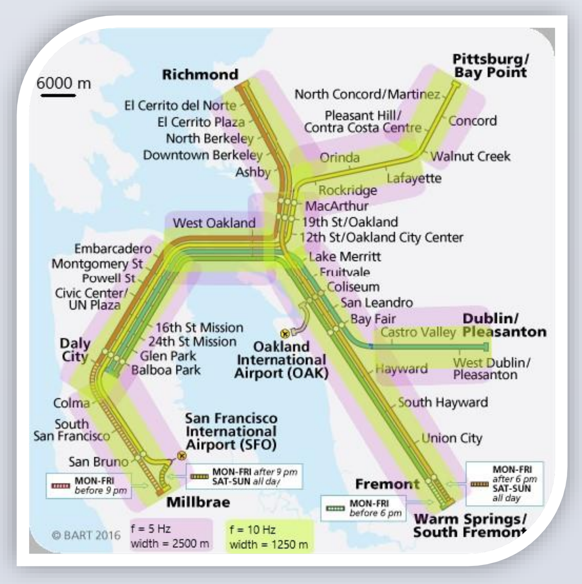
Wavelength Formula

$$\lambda = \frac{U}{f}$$

U – *velocity of propagation*

f – *sinusoidal frequency*

λ – *wavelength in Hz*



$V_{Rayleigh}$ = 250m/s		corridor width (km)			
f (Hz)	λ, wavelength (m)	30 * λ	40 * λ	50 * λ	60 * λ
20	12.5	0.375	0.5	0.625	0.75
15	16.67	0.5	0.6667	0.8333	1
10	25	0.75	1	1.25	1.5
5	50	1.5	2	2.5	3
1	250	7.5	10	12.5	15

The matrix of correlation functions obtained can be decomposed into distinct terms representing individual site responses and differential greens functions. This type of multichannel decomposition is commonly used in 3D seismic processing.

Conclusion

Since the behavior of geophones is well understood and quite predictable, an option is to use dedicated geophones as control sensors near the train while an array of smartphones is deployed within the assumed coverage zone. In principle, geophones have a much higher signal-to-noise ratio and they can be used for correlation against the rest of the cellphones.

Recording ambient noise on smartphones is feasible, but highly dependent on signal-to-noise ratio, which can be improved by having more sensitive sensors and/or recording for a relatively long period of time. Future work will consist in determining the required recording times for various wavelengths and frequencies and implementing the dense array component.

The application of such a cost-effective and time-saving method will definitely contribute to near-surface characterization and site response.

References

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