geoconvention
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September 21-23 2020
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The seismology of active transportation

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Summary

Seismic surface waves are generated by all modes of transportation on the ground surface. We focus on characterising the seismic signature of walking pedestrians, bicycles and jumping targets. Two field tests were performed on the University of Calgary campus to examine the applications of passive seismic monitoring in urban areas. Time-dependent frequency analysis of seismograms produced by different modes of active transportation are examined. The velocity of a pedestrian, 7±2 km/hr, and a slow-moving bicycle, 5±1 km/hr, are estimated using the peak power of signals at neighboring geophones. We apply footstep detection algorithms to synthetic data and other modes of active transportation, then assess their suitability for this data set. From our results, unique seismic signature of the pedestrians and bicycle are identified. Suggested improvements to method and potential applications are discussed.

Theory / Method / Workflow

The Government of Canada recently introduced a focus of designing communities to encourage and support active transportation. In response, we develop an understanding of pedestrian and cyclist behaviour through analysis of their seismic wavefields. We characterise the seismic wavefield produced by walking, cycling and jumping, using the methods of footstep detection from Reddy et al. (2010) and show the potential for geophones to be implemented in urban areas. We the presence of footsteps, jumping and cycling using two methods; the Neighbourhood Euclidean Distance Metric and the Neighbourhood ratio metric (Reddy et al., 2010). Both methods are based upon the principle that signals produced by footsteps change smoothly with time, whereas noise varies randomly in the three orthogonal components (Reddy et al, 2010). We estimate the speed of the targets parallel to the geophone array using the time differences in peak power of signal between receivers.

Results, Observations, Conclusions

We find that the intermittent nature of a series of footsteps causes the power of time segments of the signal to vary significantly. The power of segments of the signal shows uniform peaks corresponding to each event and detection is independent of waveform for a series of footsteps. The passing of a bicycle shows a gradual increase and decrease in power of the signal as the bicycle passes. For both footsteps and a bicycle, the peak power of the signal is used as a proxy for the time at which the target is closest to the receiver. Calculating the relative time between peak power at consecutive geophones allows the estimation of velocity of target parallel to geophone array. We estimate the velocity of the pedestrian as 7±2 km/hr and the bicycle as 5±1 km/hr. Note, the bicycle was a particularly slow-moving bicycle in attempt to generate larger seismic wavefield.

A human footstep and its Corresponding NED decomposition is given in Figure 1. The onset of the footstep occurs at 0.15 s ending at 0.075 s. The corresponding NED domain signal shows a low value when the footstep is present and approaches a value of 2 elsewhere. Characteristics like NED can form the basis for automated pedestrian detection.

Novel/Additive Information

Machine learning algorithms, where computer systems can compare input signals to a known data set to classify each event has already been demonstrated for pedestrian intruders by Makhopadhyay et al. (2018). Similarly, Park et al (2008) use a dynamic synapse neural network with single component geophones to discriminate between pedestrians and vehicles. We feel that our characteristics will add to these advances.

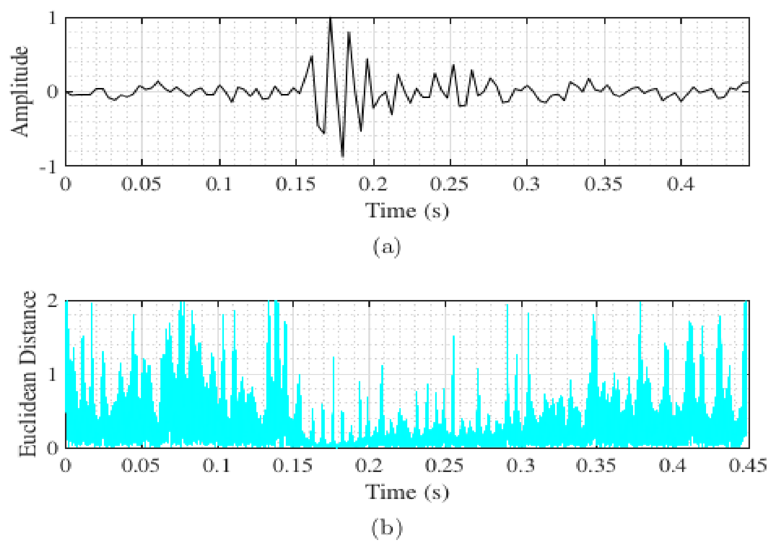

Figure 1: Example of application of the NED to a footstep event. a) Seismogram of a footstep. b) NED domain footstep.

Acknowledgements

We thank David Grindel and Brett Friedricksen of Geospace Technologies Canada Inc., Dr. Barry Phipps from the University of Calgary and Nichole Wyatt from the City of Calgary. This work was supported under the Urban Alliance Research Agreement 1046981.

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