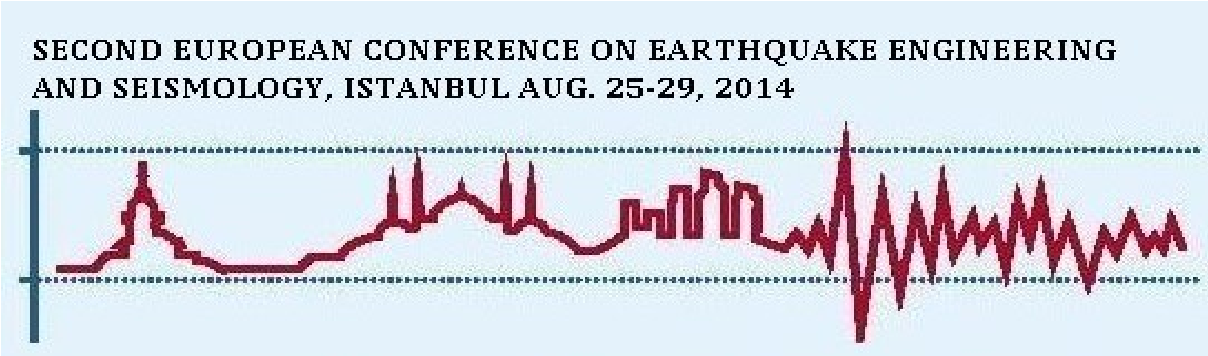

SENSOR PLACEMENT FOR THE ANALYSIS OF SEISMIC SURFACE WAVES: SOURCES OF ERROR AND DESIGN CRITERION

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Sensor arrays are used in numerous geophysical applications including site characterization using ambient vibrations. The geometry of the sensor array has a major impact on the performance of the array processing system and has been discussed extensively in literature.

Seismic surface waves can be measured by deploying an array of seismometers on the surface of the earth. The goal of such measurement surveys is, usually, to estimate the velocity of propagation and the direction of arrival of the seismic waves. In this work, we address the issue of sensor placement for the analysis of seismic surface waves from ambient vibration wavefields.

In literature different types of array have been used and the choice of a particular geometry is often not justified in a quantitative way. In Horike (1985), L-shaped and cross-shaped arrays with a regular sensor spacing have been employed. Irregularly spaced crosses were used in Asten & Henstridge (1984), Milana et al. (1996), Ohori et al. (2002) and Rost & Thomas (2002). In other works, sensors were arranged as several triangles centred around a common point (Satoh et al. 2001a,b). In Gaffet et al. (1998) and Cornou et al. (2003), concentric circles were used.

In this work, we first clarify the relationship between array geometry and the estimation error. We show how the geometry affects the mean-squared estimation error of parameters of interest, such as the velocity and direction of propagation, both at low and high signal-to-noise ratios (SNRs). In particular, we show how outliers occur at low SNR and what causes them.

After having clarified the sources of errors, we propose a cost function suitable for the design of the array geometry with particular focus on the estimation of the wavenumber of both Love and Rayleigh waves. The proposed cost function is developed from the parameter estimation problem and does not assume any prior constraint on the array geometry.

The details concerned with the implementation of the numerical approach for array optimization are omitted in this instance and they can be found in Maranò et al (2014). We show numerical experiments verifying the effectiveness of our cost function and resulting array geometry designs, leading to greatly improved estimation performance.

REFERENCES

Asten, M.W. & Henstridge, J.D., 1984. “Array estimators and the use of microseisms for reconnaissance of sedimentary basins”, *Geophysics*, 49(11), 1828–1837

Cornou, C., Bard, P.-Y. & Dietrich, M., 2003. “Contribution of dense array analysis to the identification and quantification of basin-edge-induced waves, part II: application to Grenoble basin, French alps”, *Bull. seism. Soc. Am.*, 93(6), 2624–2648

Gaffet, S., Larroque, C., Deschamps, A. & Tressols, F., 1998. “A dense array experiment for the observation of waveform perturbations”, *Soil Dyn. Earthq. Eng.*, 17, 475–484

Horike, M., 1985. “Inversion of phase velocity of long-period microtremors to the S-wave-velocity structure down to the basement in urbanized areas.”, *J. Phys. Earth.*, 33(2), 59–96

Maranò, S., Fäh, D. & Lu, Y.M., 2014. .”Sensor placement for the analysis of seismic surface waves: sources of error, design criterion and array design algorithms”, *Geophys. J. Int.*, to appear

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Milana, G., Barba, S., Pezzo, E.D. & Zambonelli, E., 1996. “Site response from ambient noise measurements: new perspectives from an array study in central Italy”, *Bull. seism. Soc. Am.*, 86, 320–328

Ohori, M., Nobata, A. & Wakamatsu, K., 2002. “A comparison of ESAC and FK methods of estimating phase velocity using arbitrarily shaped microtremor arrays”, *Bull. seism. Soc. Am.*, 92(6), 2323–2332

Rost, S. & Thomas, C., 2002. “Array seismology: methods and applications”, Rev. *Geophys., 40(*3), 2-1–2-27

Satoh, T., Kawase, H., Iwata, T., Higashi, S., Sato, T., Irikura, K. & Huang, H.-C., 2001a. “S-wave velocity structure of the Taichung basin, Taiwan, estimated from array and single-station records of microtremors”, *Bull. seism. Soc. Am.*, 91, 1267–1282

Satoh, T., Kawase, H. & Matsushima, S., 2001b. “Estimation of S-wave velocity structures in and around the Sendai basin, Japan, using array records of microtremors”, *Bull. seism. Soc. Am.*, 91(2), 206–218