FREE AND IMPROVED COMPUTER CODES FOR HVSR PROCESSING AND INVERSIONS

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Abstract

The investigation of seismic ambient noise (microtremor) in spectral ratio form, known as HVSR, is extremely popular nowadays both to investigate large areas in a reduced amount of time, and to leverage a wider choice of low cost equipment. In general, measurements at multiple locations are collected to generate multiple HVSR curves which can individually be inverted to retrieve local subsurface elastic properties. Recently, however, there has been an increasing interest on spatially correlating informative content from different locations. In this perspective, and in the broader context of a hydro-geological survey conducted at the Serravalle Sesia sedimentary basin (Italy), we collected and investigated 19 microtremor measurements with the objective of mapping the bedrock depth. In general, this requires manually extracting the main resonant frequency from individual curves and then "building" the desired map through a combined use of several software applications often resulting in a very time consuming workflow, especially for large surveys. Therefore, we developed and tested a new computer program, "OpenHVSR – Processing Toolkit", specifically engineered to process and display the informative content of data in 2D and 3D, to optimize the investigation of spatially varying properties. The obtained HVSR curves were then inverted using OpenHVSR, the counterpart code developed previously for inversion.

Introduction

The HVSR technique (Nakamura,1989) is a geophysical method that became increasingly popular in multiple fields, such as geology, geotechnics, seismology and archaeology (Bard, 1998; Mucciarelli and Gallipoli, 2001; SESAME Project 2005; Castellaro et al., 2005; Obradovic et al., 2015; Abu Zeid et al., 2016, 2017, Bignardi et al. 2017), mostly because measurements are performed in matter of minutes and because it only requires one operator and low cost equipment. Since data acquisition is so versatile, the typical HVSR survey often consists of a multitude of measurements, performed at different locations. In the broader context of a hydro-geological survey at the Serravalle Sesia sedimentary basin (Italy), performed to optimize the exploitation of hydrological resources, we decided to use the HVSR technique to gain insight into the subsurface elastic properties, and in particular, to estimate the bedrock depth. A survey with measurements from 19 different sites was performed. In general, the HVSR processing consist of splitting each three-component seismic record into several windows to compute an equal number of spectral ratio curves. The average spectral curve (the HVSR-curve) is then computed. The main characteristic of such a curve is that it presents one or more peaks at the the subsurface resonant frequencies. Data windows which contain transient signals should be discarded in this process. Various software platforms have different desirable features for this critical task. For example, the software Geopsy (geopsy.org) plots the HVSR curve for each window in the same graph so that anomalous-looking curves can be easily recognized and discarded before the average is computed. The software Grilla (www.tromino.eu), on the other hand,

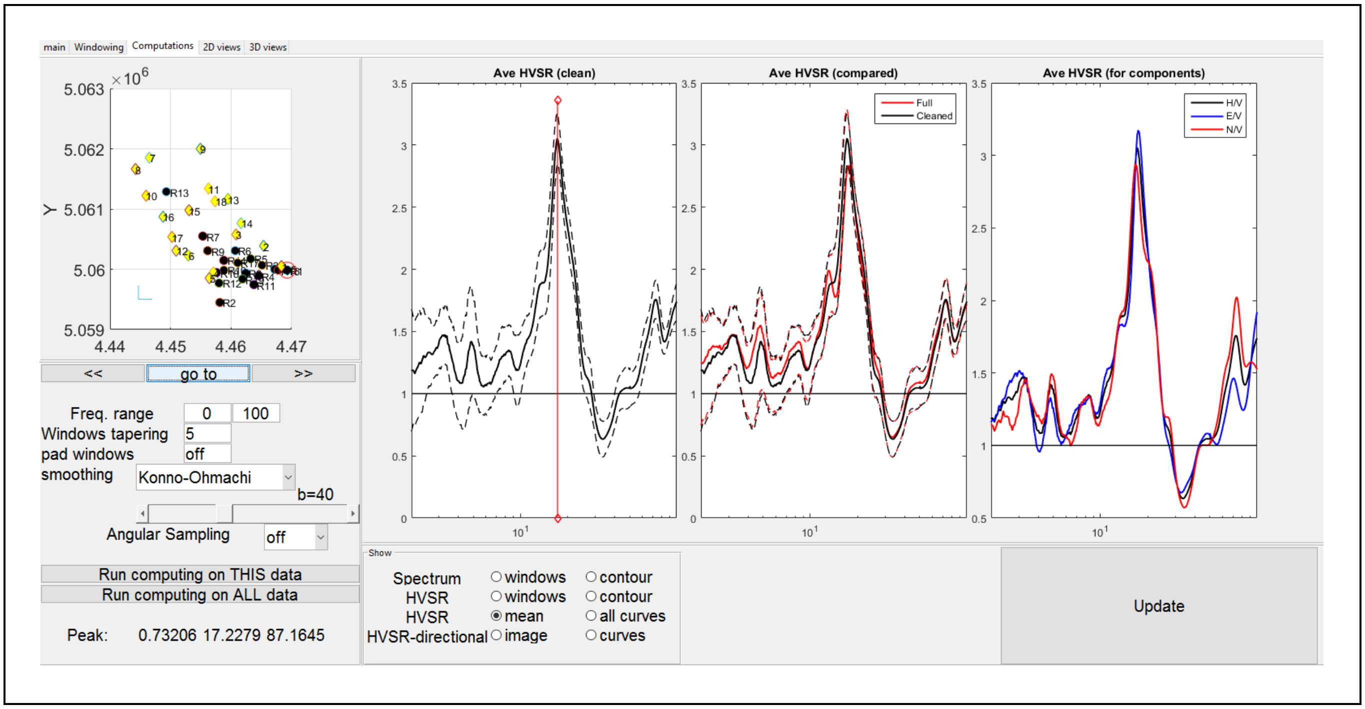

Figure 1: Example of data elaboration using "OpenHVSR Processing Toolkit". The processing result concerning the first of a set of 19 measurements is shown as an example.

tiles HVSR curves side-by-side in time-frequency view, so that discontinuities in peaks across time are highlighted. As HVSR surveys typically involve the processing of multiple measurements, Geopsy can save and reuse the processing parameters while Grilla actually handles all the measurements in the same interface.

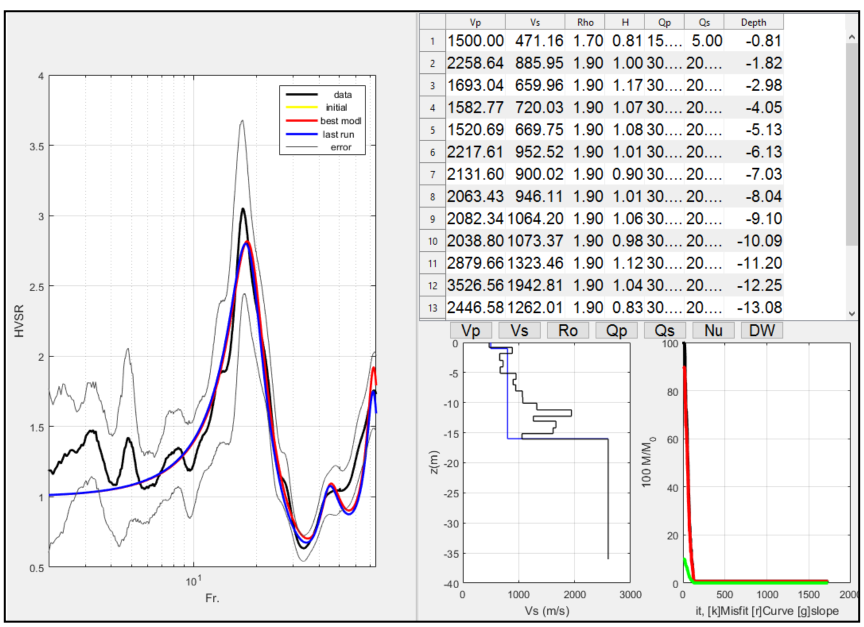

Figure 2: Example of Inversion result obtained for the curve in figure 1 using the software "OpenHVSR". Curve fitting is shown on the left panel, while the subsurface model is shown on the top-right. The Vs profile and misfit minimization progress are shown at the bottom-left

Method

Nowadays, the correlation of informative content obtained from distributed locations is gaining a growing interest (Ibs-von Seht and Wohlenberg, 1999; Bignardi et al, 2014; Bignardi 2017; Mantovani et al. 2017). Even at the processing level, for example, the map of the main resonant frequency (F_0) on the investigated area represents a good indication of subsurface morphology. Since no specific software exists for bedrock mapping, which typically involves manual extraction of F0 values and construction of the desired depth map through a combined use of several software programs, we decided to develop and test a novel computer program "OpenHVSR-Processing Toolkit" (Figure 1). It has been specifically engineered to enhance HVSR processing- with the purpose of spatially correlating different forms of informative content from the data, (e.g. main resonant frequency, main peak amplitude, the signal's preferential arrival direction), and to display the results in 2D and 3D. The program aims at implementing the most effective and desirable tools present in other commercial and non-commercial alternatives, all in one bundle, freely available to the scientific community. Concerning inversion (Figure 2), we used the open-source code OpenHVSR (Bignardi et al., 2016).

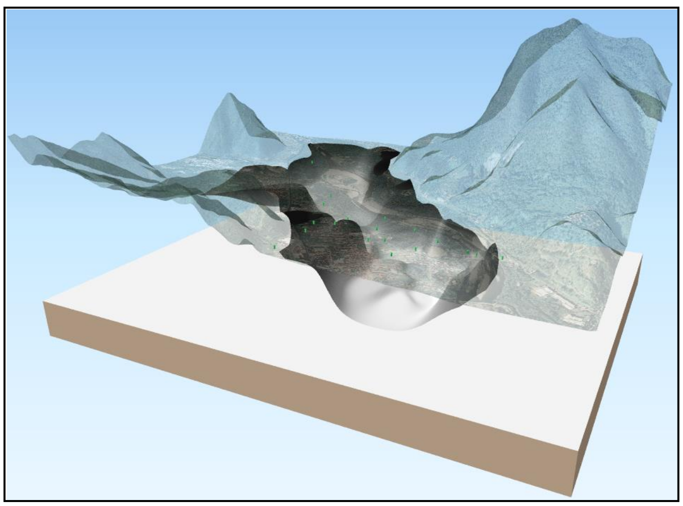

Figure 3: Three-dimensional view of Serravalle Sesia sedimentary basin (Italy). Land topography (DEM) and estimated depth of bedrock were imported in QGIS to produce a navigable map to aid interpretation and decision making.

Conclusions

On a dataset comprising 19 microtremor measurements, acquired at the Serravalle Sesia valley (Italy), we tested the processing capabilities of our new computer program "OpenHVSR Processing Toolkit" and performed inversion using our previous code OpenHVSR. We showed that operating at the processing level, with a tool specifically engineered to extract different forms of spatially varying information, a deeper understanding the data is possible. In addition, properties beyond F_0 can be extracted. Processing and map production speeds are dramatically improved as well. Furthermore, HVSR curves are directly exportable in OpenHVSR for inversion. Finally, the obtained 3D bedrock model can be directly exported to QGIS in order to obtain, with minimal manual effort, an effective and graphically attractive map for decision and intervention purposes.

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