Introduction

We are continuing to explore the use of the accelerometer in smartphones to detect earthquakes and the potential scientific applications of using such a dense network. Although the smartphone network does not exist at this point, we are starting to think about how we could use the data for scientific research and applications by using an analogous dataset. We are using the Nodal Seismic Array deployed by the NodalSeismic Company. This array has a nominal station spacing of about 120 m and was designed for active source exploration of petroleum resources. It occupied over 5200 sites with 10 Hz vertical component seismometers in the heavily urbanized area of Long Beach, CA. The dimensions of the array are 7 km by 10 km.

Methodologies

(1) P-wave arrival time residual

We first picked the P-wave arrival time of a magnitude 2.4 earthquake (2011-05-14 04:19:15) for each of the stations using the STA/LTA algorithm (Allen 1978) combined with manual picking. Then we extracted a 1D structure model from the 3D velocity model for southern California (Magistrale et al. 1996). We used TauP package (Crotwell et al. 1999) to predict the arrival time of the P wave using the extracted velocity model. We then subtracted the observed travel time from the predicted time. Removing the linear trend produced the residual travel time map in Figure 2.28.1

(2) Helmholtz Tomography

We implemented the Eikonal/Helmholtz tomography method first proposed by Lin et al. 2009. This method uses the Eikonal equation (e.g. Wielandt 1993; Shearer 1999)

\[
\frac{1}{c_i(r)^2} = |\nabla \tau(\tau_i, r)|^2 - \frac{\nabla^2 A_i(r)}{A_i(r)\omega^2}
\]

which is derived directly from the Helmholtz equation. In this equation, \( c_i \) is the phase speed for travelttime surface \( i \) at position \( r \), \( \omega \) is the frequency and A is the amplitude of an elastic wave at position \( r \). From this equation, we can directly relate the travel time of the waves with the phase velocity at each station point without doing an inversion. Using the above equation to get the phase velocity is called Helmholtz tomography. If high frequencies are used, or the spatial variation of the amplitude field is small compared with the gradient of the travel time surface, then the second term on the right-hand side can be dropped. This forms the basis of Eikonal tomography. Lin applied this Eikonal tomography to ambient noise of this dense array and then inverted this into a 3D structure. We apply this Helmholtz tomography method to the same earthquake we used above, and get a phase velocity structure as shown in Figure 2.28.2.

Initial results and future work

From the two figures, we can see some evidence of the shallow structure in this area (the depth of the earthquake is 11.9 km, and the distance from the epicenter to the edge of the array is about 6.5 km). Some obvious structures associated with the faults can be seen. With only one small earthquake, it is hard to tell the real structure in this area. But this shows the potential of using the dense network, like the smartphone network, to study the earth structure. We are now developing our 2nd generation application for the smartphones for collecting earthquake data, and building a prototype smartphone network with Deutsche Telecom (Silicon Valley Innovation Center). A network consisting of these smartphones may work as a supplement network to the current traditional network for scientific research and real-time application.
Figure 2.28.2. P wave phase velocity computed from the Helmholtz tomography. The red areas are slow velocities and the blue areas are fast velocities. The black lines are the faults in this area.

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References