Application of structured regularization to seismic tomography for adaptation to discontinuities

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Seismic tomography is a method for estimating the velocity structure of seismic waves propagating in the Earth, based on arrival times of seismic waves recorded by seismic observation networks. Grid points are placed in three-dimension to estimate velocity parameters and their heterogenous distributions. A value of velocity at an arbitrary point is calculated by interpolating them at the nearest eight grids. The SIMUL2000 (Thurber, 1993) is a widely-used estimation algorithm that estimates velocity parameters based on minimizing the sum of squared residuals.

In seismology, it is well known that there are regions of varying velocity drastically, such as the Moho discontinuity, in the vertical (depth) direction. On the other hand, in the horizontal direction, velocity changes are generally smooth, that is, rapid changes of the velocity is less likely to occur. In this presentation, we propose a new tomographic method based on structured regularization to incorporate such structural properties of the Earth's interior.

We use different penalty terms in the vertical and horizontal directions to express the above-mentioned properties in seismic velocity changes. For the depth direction, we employ a penalty term that has a form of l1-sum of l2-norm of the second-order differences of the horizontal units. This penalty term is intended to represent the sharp velocity jumps associated with the presence of discontinuities, by making average velocities in the depth piecewise linear. On the other hand, in the horizontal direction, we set a penalty term based on the l2-norm to express smooth velocity trends.

In the presentation, we conduct numerical experiments to discuss properties of the proposed methods by comparing to conventional methods, SIMUL2000 with the Laplacian regularization. We show that the proposed method is superior to the conventional ones in estimating velocity structures, especially in terms of accuracy in the presence of discontinuous increasing in seismic velocity.

Keywords: Seismic tomography, Velocity structure, Computational seismology, Velocity discontinuity, Structured regularization

