Seismic travel time tomography method using hierarchical shape function of FEM

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In travel time tomography, earthquakes and observation stations are not uniformly distributed, so, calculating ray paths, we obtain various ray density distribution. In order to obtain the velocity distribution of various spatial resolutions according to the ray density, we show that hierarchical shape function of FEM (Finite Element Method) as velocity interpolation function is very useful.

Target region is divided into sub-regions (called as elements in FEM), in which the velocity or slowness value and its derivatives are calculated by interpolating each values at points (called as nodes in FEM) located at corners (and boundaries) of the element. Pseudo-bending method (Um and Thurber, 1987) is widely used to calculate ray path in the seismic tomography. In this method, velocity (or slowness) value should be continuous across the element boundary and the first derivative should exist within the element. When we use the hierarchical shape function as interpolation function, the above conditions are satisfied. Using higher order polynomials, we obtain the interpolation function of higher spatial resolution. To save CPU time, rectangular element is appropriate, because it is simple to find quickly in which element a new bended point of the ray is located.

We apply this method to test travel time dataset and real dataset observed in Kanto-Tokai area and obtain the result. We use the fourth-order hierarchical shape function. When the fourth-order function is used in all elements, large computer memory is required. But, reducing the order, the memory can be saved drastically. To determine the order of the function of each element, ray density of each element is used. Ray number, ray travel time and ray vector can be used as the ray density. The ray number is simple, but ray direction is ignored. Intuitively, the ray vector will be adequate. Of course, ideally, a method based on resolution analysis of matrix will be the best.