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A comparative study between multiple inverse method and Hough-transform-based inverse method for stress estimation

Katsushi Sato[1*]

[1]Div. Earth Planet. Sci., Kyoto Univ.

This presentation aims to demonstrate advantages and disadvantages of two stress inversion methods, multiple inverse method (MIM, Yamaji, 2000) and Hough-transform-based inverse method (HIM, Yamaji et al., 2006). Recently, both the methods have come to be widely used, mainly because of the capability of detecting plural stress solutions from a population of heterogeneous faults or earthquake focal mechanisms.

The present methods are commonly composed of two processes; (1) calculating fitness of all possible stress to the fault population and (2) finding local maxima of fitness to enumerate likely stress solutions. The essential difference between MIM and HIM lies in the process (1). The fitness of stress is 'visualized' as a distribution of values on five-dimensional (5-D) unit sphere on which points have one-to-one correspondence to reduced stress tensors (Sato and Yamaji, 2006). A reduced stress tensor, which is the desired solution of stress inversion problem, has four variables specifying orientations of three principal stress axes and the stress ratio. Given a fault datum, HIM checks a region on 5-D unit sphere where the allowable stresses lie. The fitness distribution in HIM is simply composed by superposing the allowable regions for all fault data.

The fitness distribution in MIM has sharply exaggerated peaks at likely solutions. MIM firstly extracts a subset of several (usually four or five) faults from a whole data set and determines an optimal stress solution for them. Then, all possible combinations of fault subsets are sampled with replacement, and numerous optimal stress solutions are determined. The density distribution of solutions on 5-D unit sphere is interpreted as the fitness distribution. The stress solutions for heterogeneous fault subsets are expected to be scattered, while those for homogeneous subsets are to be concentrated. Therefore, the resampling of homogeneous subsets emphasizes density peaks of likely stresses.

For the purpose of confirming the above-mentioned feature, an artificial fault data set was analyzed by MIM and HIM. The data set includes 100 faults activated by stress A and 50 faults by stress B. The two stresses are distanced by 120 degrees on 5-D unit sphere. MIM produced two narrow peaks of fitness corresponding to the expected solutions. The peak of stress A was 6.8 times higher than that of stress B. Meanwhile, HIM resulted in broad peaks at correct locations. The ratio of the heights of stresses A to B was 1.7 to 1. These results show that MIM has an advantage in detecting primary stress solution from noisy data. However, MIM simultaneously makes it diffcult to obtain stresses responsible for relatively smaller number of faults. On the other hand, the height of fitness peak in HIM is approximately proportional to the number of faults. The strong point of HIM is the detectability of weaker signals.

The practical differences between MIM and HIM are in computational cost and in availabe data source. MIM requires a long computational time owing to the resampling process, while HIM achieves linear order computation. Sato (2006) improved HIM to analyze incomplete fault data such as ones without slip orientation or without shear sense. The method is useful for geological faults and faults found from remote sensing observation.

This presentation also introduces recent trials of improving the process (2) of peak detection for objective determination of plural stress solutions.

References

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