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How many stress tensors should be detected from a heterogeneous fault-slip dataset?

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Recently, several techniques of stress tensor inversion have been proposed for detecting multiple stresses from a set of fault-slip data (e.g. Nemcok and Lisle, 1995; Yamaji, 2000). A dataset is called 'heterogeneous' if the faults originated in more than one stress state. Owing to temporal and spatial variation of stress field, a dataset is more or less heterogeneous especially for ancient faults of geologic ages. Although the above-metioned techniques enable us to recognize multiple stresses, they have difficulty in determining the nuber of stress tensors to be detected. We approach this problem by using minimum description length (MDL) criterion to determine the optimum mixed distribution model to approximate the distribution of objective function in the parameter space.

The present method is divided into the following three steps. Firstly, the Hough transform method (Yamaji et al., 2006) is employed to obtain the fitness distribution in the parameter space as the objective function to be maximized, which evaluates fitness of all possible reduced stress tensors to a set of fault-slip data. Since reduced stress tensors are equivalent to points on the five-dimensional (5-D) unit sphere (Fry, 1999; Sato and Yamaji, 2006), the fitness distribution can be expressed as a probability distribution on the unit sphere. Our task is to recognize multiple peaks of the fitness distributuion. Secondly, a model of mixed 5-D von Mises-Fisher (vMF) distribution is fitted to the fitness distribution by EM algorithm. The vMF distribution is one of the simplest unimodal and isotropic distribution on multi-dimensional sphere. The mean vector of each component distribution shows the probable reduced stress tensor, i.e., the solution for the stress tensor inversion, while the concentration parameter indicates the stability of solution. Finally, by changing the number of component vMF distributions, the optimal mixed distribution model is chosen in order to minimize the the MDL criterion.

Numerical experiments were executed to validate the present method with artificial fault-slip datasets originated in several stresses. For most cases, the correct numbers of solutions were selected by MDL criterion. However, it was found that the optimized number of solutions tends to increase with the number of faults which exceeds hundreds to thousands. This fact implies that the mixed vMF model is too simple to express the fitness distribution on the 5-D unit sphere in detail. Except for this problem, the present method provides an index of number of stresses recorded in a heterogeneous fault-slip dataset.