boundary integral equation method of dynamical elastic problems accelerated by H-matrix method, and its suggesting application to frictional properties of real fault systems

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In recent years, with the development of earthquake science, it has become possible to simulate what kind of physical process the actual fault rupture has occurred. One important characteristic of this forward modeling is the frictional strength estimation of the fault. In the current earthquake science, aftershocks are understood as delayed faulting of the main shock [e.g. Dieterich, 1994], and some main shock events seems to be able to be understood as a delayed faulting of their foreshocks. For example, in the 2016 Kumamoto earthquake, a main shock occurred about one day after its foreshocks. It is expected that forward modeling will be of great help in discussing earthquake-earthquake interactions through these frictional strengths, which cannot be understood only by the stress.
On the other hand, handling of nonplanar fault geometries seen in inland faults and the like has caused a cost problem of simulation. In forward modeling, boundary integral equation method is standardly used in seismology as a highly accurate solution that can handle stress divergence at the fault breaking tip with high accuracy. Currently, the cost of the simulation increases significantly for non-planar faults when compared with planar fault shapes with a 90 degree tilt angle many simulation examples adopts. The cost ratio is roughly proportional to the number of boundary elements *N*. In the current large scale simulation, *N* is approximately several thousands to several tens of thousands. Because of this extreme cost increase, forward modeling of a system having a complicated fault geometry such as an inland fault remains as a big problem of earthquake science yet.
In order to solve this cost problem, we developed a new algorithm, the FDP = H-matrix method, which applies the fast domain partitioning method (FDPM) [Ando, 2016] and the Hierarchical matrix method (H-matrix method) [Hackbusch, 1999] to the dynamical boundary integral equation method. In this presentation, we present the outline of this algorithm and its application examples and discuss suggestions for fault friction estimation. FDP = H-matrix method is the method that the theoretical computational complexity of the stress convolution and the memory cost can be suppressed on the order of *N log N*. Although its cost is lower cost than the conventional spectral method to the planar faults [Perrin et al., 1995], it can be applied to nonplanar fault geometries. This is an algorithm for potentially solving the conventional cost problem of the boundary integral equation method. FDP = H-matrix method by utilizing the FDPM which divides the stress integral kernel into P and S waves, the near-field term, and the secular term; the impulsive wave domain is thus efficiently treated, and FDP=H-matrix method has memory lightweight and computaional speed which could not be achieved by applying only the H-matrix method. Using this method, we will simulate fault motions on complex geometries as seen in the inland faults.

Keywords: fault forward modeling, dynamical boundary integral equation method, Hierarchical matrix method