

ABSTRACT: A new dynamic slip node formulation for the representation of "continuous discontinuities" in geodynamic numerical models

Valeria Fedeli - University of Milano, Department of Earth Science "A. Desio" - valeria.fedeli@unimi.it

Graduation session 26/09/2023

Discontinuities affect the Earth's dynamics, but in geodynamical modeling the Earth is often represented as a continuous material. The difficulty in representing discontinuities in numerical models has been addressed in several ways in literature. The split node method, originally introduced by Jungels (1973) and Jungels and Frazier (1973) for elastic rheology and then modified by Melosh and Raefsky (1981) to simplify its implementation, permits to introduce a discontinuity into a finite element model by fixing an a-priori slip at a node where the displacement depends on the element which the node is referred to. Originally this method requires the discontinuity's geometry and slip to be established a-priori.

More recently, Marotta et al. (2020) modify this approach introducing a coupling factor c_f that indicates the percentage difference between the velocities of the element which the slip node belongs to, while the velocity consistently derives from the dynamic evolution of the system. However, the discontinuity's geometry is an a-priori constraint.

The aim of this thesis project is to elaborate a new technique that allows a dynamic identification of the discontinuity's position during the thermomechanical evolution of the system based on physical parameters, without imposing the slip nor the geometry.

To achieve this goal I implemented a new algorithm that identifies and introduces one or more discontinuities in a finite-element model following two phases: nucleation and propagation. These occur by choosing a yield physical property and determining the potential slip nodes, i.e. nodes on which the physical property exceeds a yield value. Then, the nucleus is identified as the potential slip node at which the chosen property exceeds most the yield. Propagation can be performed by choosing between three approaches of propagation: single simple fault, multiple simple fault and single double fault; and three schemes for the identification of neighboring nodes: grid-bounded, pseudo-free and free. The discontinuity is the line connecting the nucleus node and the propagation nodes. Finally, through the assembly of a polygon including the discontinuity and three vertices of the model, elements to the right and to the left to the discontinuity are identified, and the coupling factor is assigned.

The algorithm has been tested through both simple and complex finite-elements models. Here I present two simple models (ASN RUN8 and ASN RUN9) whose purpose was to verify the dynamic process of nucleation and propagation, and three complex models (OC3 orig, OC2 80 and OC2 30), which aimed to verify the localization of the discontinuity.

Both model sets demonstrate that the objective of creating an algorithm capable of recognizing yield conditions and introducing a discontinuity in a finite-element model is achieved, as both simple and complex models demonstrate the correctness of the propagation's geometry. Moreover, the algorithm correctly recognizes and identifies left and right elements, so that the coupling factor can be easily introduced.

This work opens the possibility to future improvements of the algorithm, including the complete linking of the algorithm to a complex model, the implementation of a regridding when the free scheme is used, the improvement of the multiple simple fault approach and the implementation of new conditions that constraints the discontinuity's propagation.

REFERENCES

- Jungels, P.H. (1973). "Models of tectonic processes associated with earthquakes". PhD thesis. California Institute Technology, Pasadena, California, p. 207.
- Jungels, P.H. and G.A. Frazier (1973). "Finite element analysis of the residual displacements for an earthquake rupture: source parameters for the San Fernando earthquake". In: *Journal of Geophysical Research* 78 (23), pp. 5062–5083. DOI: 10.1029/JB078i023p05062.
- Marotta, A.M., F. Restelli, A. Bollino, A. Regorda, and R. Sabadini (2020). "The static and time-dependent signature of ocean-continent and ocean-ocean subduction: The case studies of Sumatra and Mariana complexes". In: *Geophysical Journal International* 221 (2), pp. 788–825. DOI: 10.1093/gji/ggaa029.
- Melosh, H.J. and A. Raefsky (1981). "A simple and efficient method for introducing faults into finite element computations". In: *Bulletin of the Seismological Society of America* 71 (5), pp. 1391–1400. DOI: 10.1785/BSSA0710051391.