Introduction
Earthquake ruptures are highly nonlinear phenomenon with spatio-temporal complexity on multiple scales. Furthermore,
- faults can be non-planar,
- small-scale heterogeneities and/or material nonlinearity usually exist within the fault zone.

The two categories of numerical methods traditionally used to address the problem are:
- **Finite Difference/Finite Elements Methods**
  - Able to handle nonlinearities/heterogeneities
  - Computationally demanding
- **Spectral Boundary Integral Methods**
  - Computationally efficient
  - Limited to linear-elastic homogeneous bulk

Research Objective
Develop a numerical algorithm that is capable of long-time simulation of earthquake cycles in a bulk that may have material heterogeneity, material nonlinearity or fault surface complexity.

Methodology

**Slip-Weakening Fault with LVZ**

\[
\text{Predict } u_i^T(t + \Delta t) \text{ as }
\]
\[
u_i^T(t + \Delta t) = u_i^T(t) + \Delta V_i^T(t).
\]

**SCEC Benchmark Problem TPV205-2d**

\[
\text{Predict } V_i(t + \Delta t).
\]

**Set** \(V_i^T(t)\) equal to \(\frac{1}{2} V_i^T(t) + V_i^T(t + \Delta t)\).

**Predict** \(\tau_i(t + \Delta t)\) on the virtual boundaries.

**Predict** \(\tau_i(t + \Delta t)\) at interior nodes.

**Predict** \(V_i(t + \Delta t)\).

Results

Conclusions
- The hybrid method gives accurate results when compared to pure FEM/FD.
- The method converges upon refinement.
- The method can be used for long-time simulation of earthquake cycles on faults with nonlinearities and heterogeneities.
- The absence of artificial wave reflections suggests that the method can be used as an accurate near-field wave truncation algorithm.

Future Work
- Implementing more realistic friction laws.
- Implicit FEM/FD to allow for adaptive time-stepping.
- Non-planar faults.

References

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