A Support-Operator Method for Rupture Modeling

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Discretization Method

On a curvilinear mesh, form operators that obey a discrete analog of the adjoint relation between gradient and divergence. Based on the Support Operator method of Shaskov.
Derivation

\[ f(\xi) = \sum_{\alpha, \beta, \gamma=0}^{n} N_{\alpha \beta \gamma}(\xi) F_{\alpha \beta \gamma} \]

\[ \nabla f = \frac{\partial f}{\partial \xi} \cdot J^{-1} \]

\( (D_i F)_{jkl} \approx \partial_i f(\xi = 0) \quad \text{One-point quadrature} \)

or

\( (D_i F)_{jkl} \approx \frac{1}{V_{jkl}} \int_V \partial_i f \, dV \quad \text{Mean stress} \)
Adjoint Relation

\[
\int_V f\partial_i w_i \, dV + \int_V w_i \partial_i f \, dV = \int_S f w_i \, dS_i
\]

\[
\sum_{j,k,l=1}^{m,n,p} F_{jkl} (D_i W_i)_{jkl} = \sum_{j,k,l=1}^{m-1,n-1,p-1} -(D_i F)_{jkl} (W_i)_{jkl}
\]
PML Absorbing Boundaries

\[ \dot{g}_{ij} + d_j g_{ij} = \partial_j v_i \]

\[ w_{ij} = \lambda \delta_{ij} \sum_k g_{kk} + \mu (g_{ij} + g_{ji}) \]

\[ \dot{p}_{ij} + d_j p_{ij} = \partial_j w_{ij} \]

\[ f_j = \sum_i \dot{p}_{ij} \]

\[ \dot{v}_i = \frac{f_i}{m} \]

note: summation convention not used here.
Point Source
SCEC Rupture Validation Workshop
Problem ver. 3
white: 50m rectangular, blue: 100m rectangular, yellow: 100m sheared
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PI: mode II point, PA: mode III point
Challenges for large problems

- Large propagation distances
- Non-planar faults
- Topography
- Spatial resolution for rupture dynamics
- Frequency resolution for seismic hazard
Portability

- Linux: Intel, GNU Fortran 95, MPICH2
- Solaris: Sun Workshop Fortran 95
- SDSC DataStar: IBM Power4+, XL Fortran
- SDSC Teragrid: IA64, Intel Fortran 95, MPICH-GM
- SDSU Babieca Cluster: Intel Xeon, PGI Fortran 95, MPICH-GM
Weak scaling where problem size is proportional to number of processors, and perfect scaling is a horizontal line.
Summary of Capabilities

• Support-Operator method on curvilinear meshes
• Rupture Dynamics on non-planar faults
• PML absorbing boundary
• Portable and scalable

Future work

• Attenuation