Adaptive Dynamic Fracture using Nonlinear Cohesive Zone Modeling

Sofie E. Leon[1], Kyoungsoo Park[1], Rodrigo Espinha[2], Waldermar Celes[2], Glaucio H. Paulino[1]

[1]*Department of Civil and Environmental Engineering, University of Illinois at Urbana-Champaign, U.S.A.*

[2]*Computer Science Department, Pontifical Catholic University of Rio de Janeiro, Rio de Janeiro, Brazil*

Research Objectives

- Develop an integrated, multiscale computational framework for dynamic fracture, microbranching, and fragmentation
- Employ the potential-based constitutive model for mixed-mode cohesive zone modeling
- Develop systematic adaptive mesh refinement and coarsening (AMR+C) schemes for dynamic cohesive fracture simulation in 2D and 3D

PPR: Potential-Based Cohesive Model

$$\psi = \min(\phi_n,\phi_t) + \left[\Gamma_n\left(1-\frac{\Delta_n}{\delta_n}\right)^{\alpha} + \langle \phi_n - \phi_t\rangle\right]\left[\Gamma_t\left(1-\frac{|\Delta_t|}{\delta_t}\right)^{\beta} + \langle \phi_t - \phi_n\rangle\right]$$

$$T_n(\Delta_n,\Delta_t) = -\alpha\frac{\Gamma_n}{\delta_n}\left(1-\frac{\Delta_n}{\delta_n}\right)^{\alpha-1}\left[\Gamma_t\left(1-\frac{|\Delta_t|}{\delta_t}\right) + \langle \phi_t - \phi_n\rangle\right]$$

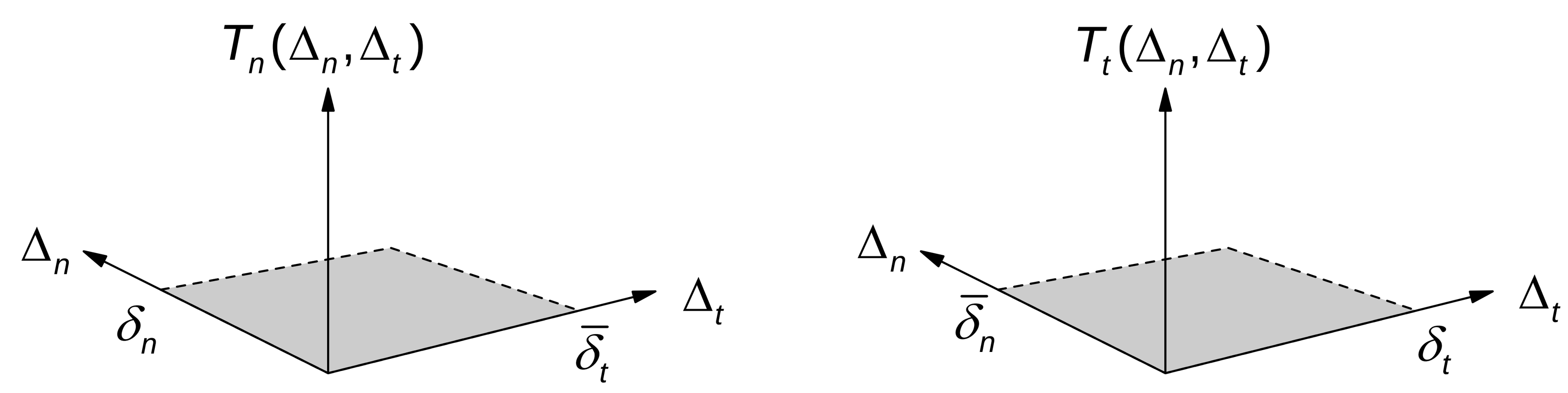
$$T_t(\Delta_n,\Delta_t) = -\beta\frac{\Gamma_t}{\delta_t}\left(1-\frac{|\Delta_t|}{\delta_t}\right)^{\beta-1}\left[\Gamma_n\left(1-\frac{|\Delta_n|}{\delta_n}\right) + \langle \phi_n - \phi_t\rangle\right]\frac{\Delta_t}{|\Delta_t|}$$

Fracture parameters

Fracture Energy: ϕ_n, ϕ_t Cohesive Strength: σ_n, σ_t

Shape Parameters: α, β

Softening region



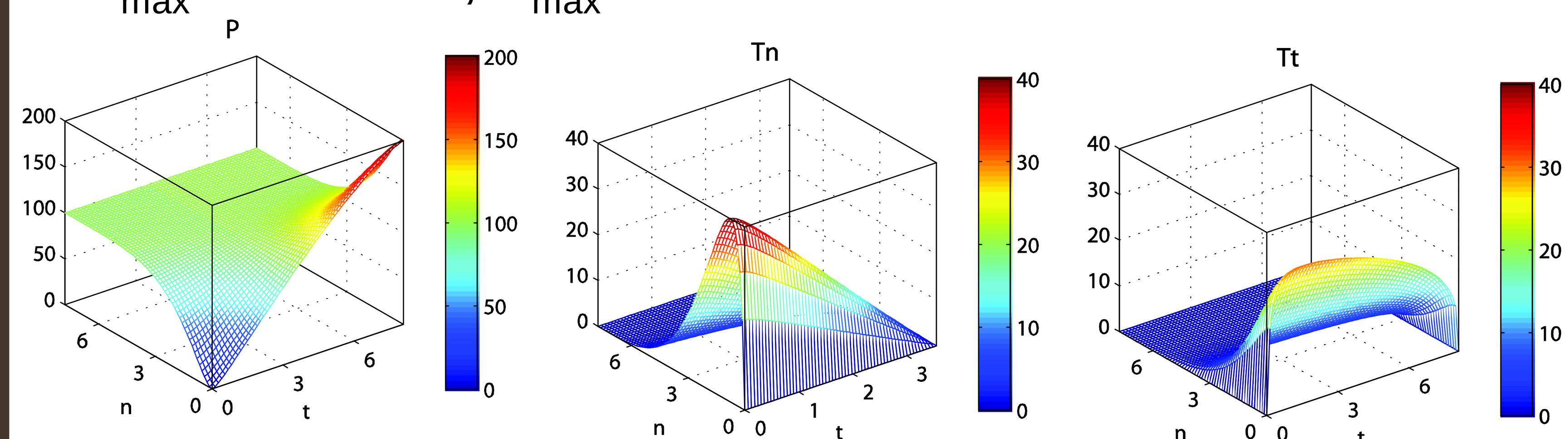
$$\delta_n = \frac{\alpha\phi_n}{\sigma_{max}} \qquad \delta_t = \frac{\beta\phi_t}{\tau_{max}}$$

$$\bar{\delta}_t = \delta_t - \delta_t\left(\frac{\langle \phi_t - \phi_n\rangle}{\phi_t}\right)^{1/\beta} \qquad \bar{\delta}_n = \delta_n - \delta_n\left(\frac{\langle \phi_n - \phi_t\rangle}{\phi_n}\right)^{1/\alpha}$$

Constitutive relationship

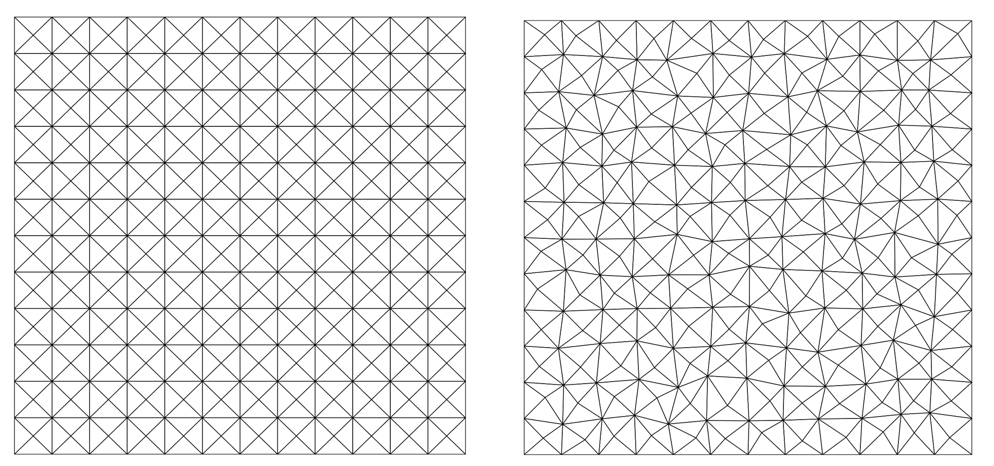
$\phi_n = 100\text{N/m},\ \phi_t = 200\text{N/m}$ $\alpha = 5,\ \beta = 1.3$

$\sigma_{max} = 40\text{MPa},\ \tau_{max} = 30\text{MPa}$

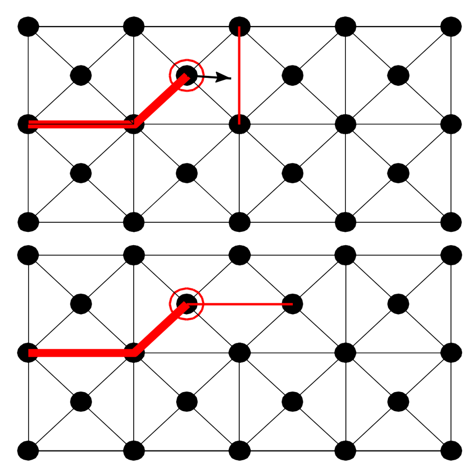


Adaptive Topological Operators

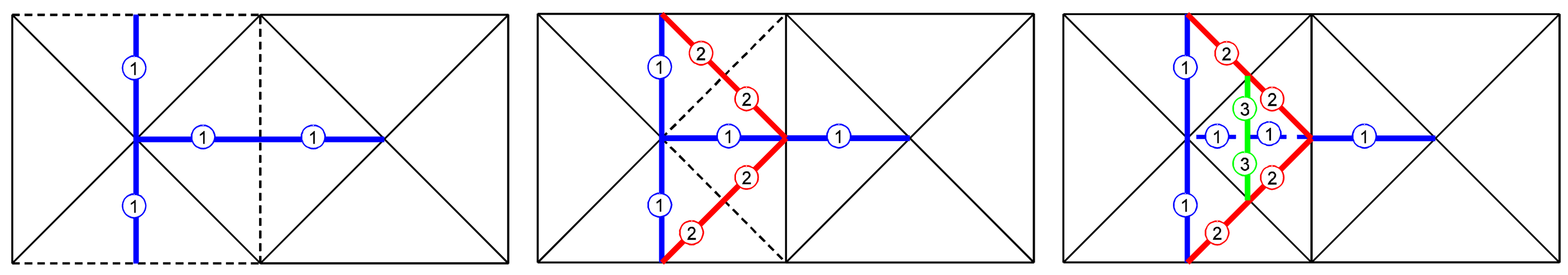
Nodal Perturbation



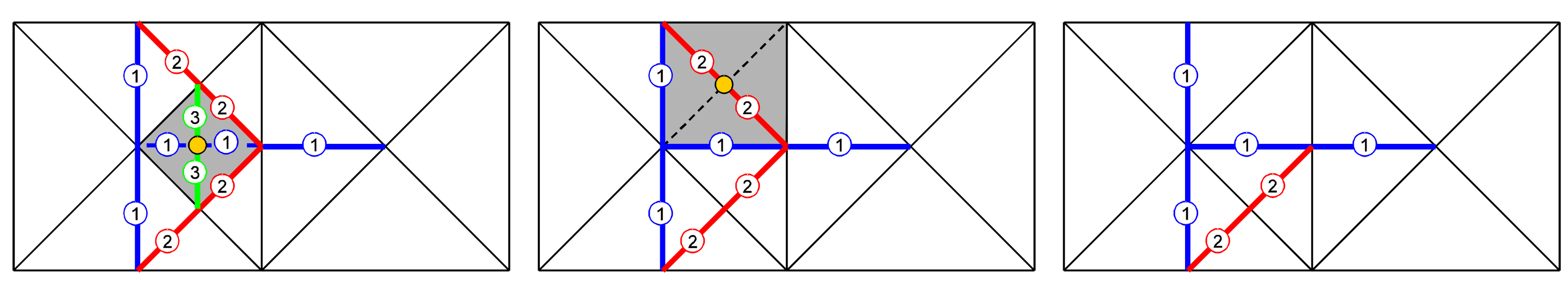
Edge Swap



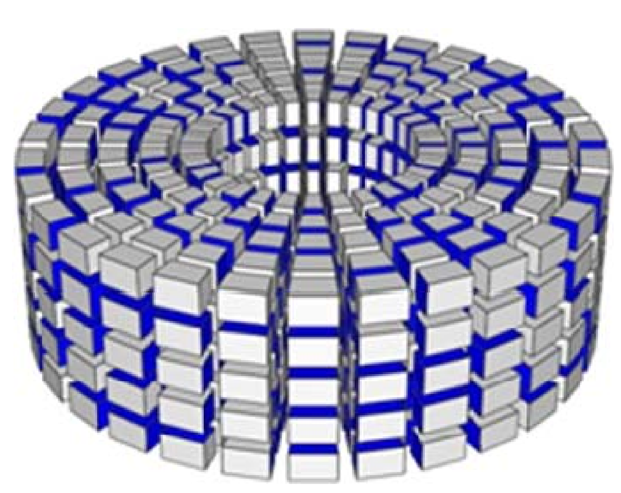
Edge Split (Refinement)



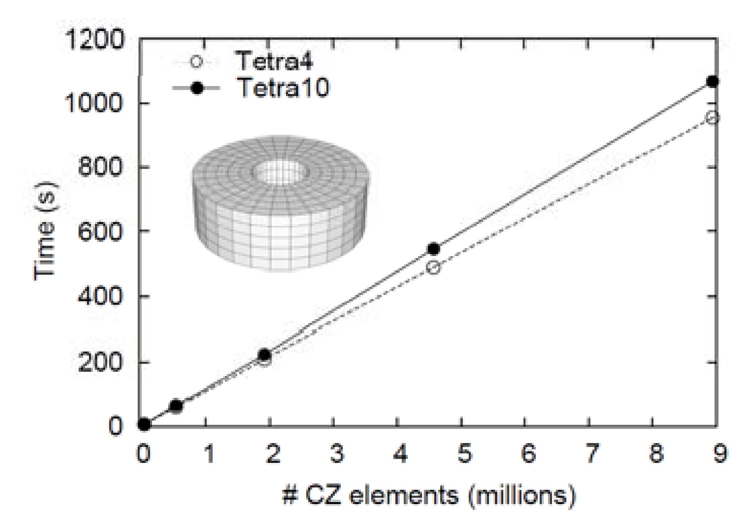
Vertex Removal (Coarsening)



Insertion of cohesive elements in three dimensions



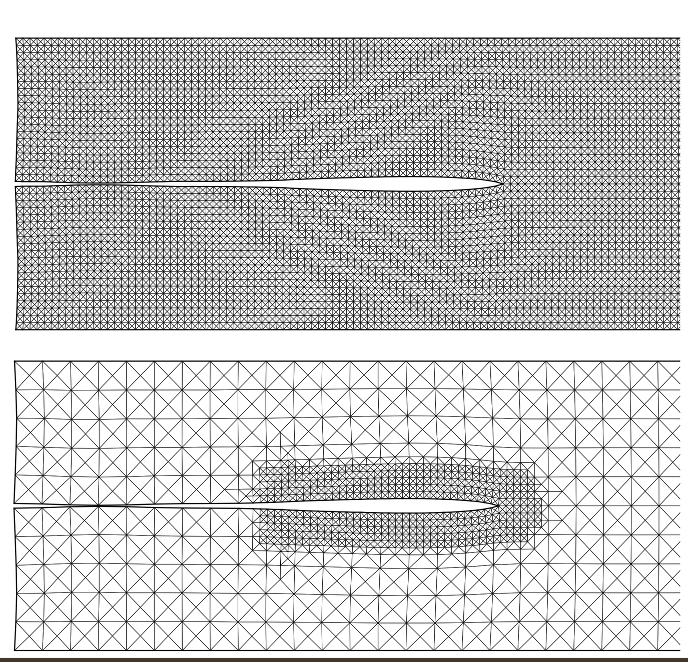
Cohesive elements randomly inserted at 20% of the facets

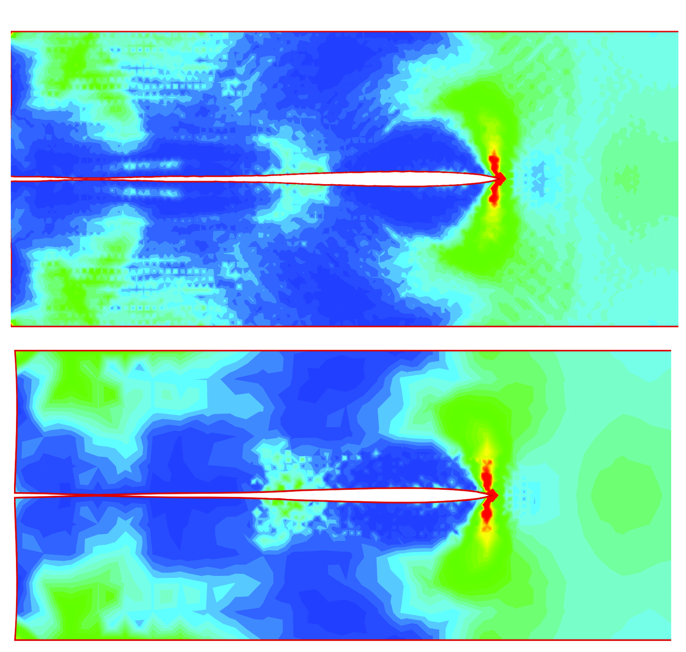


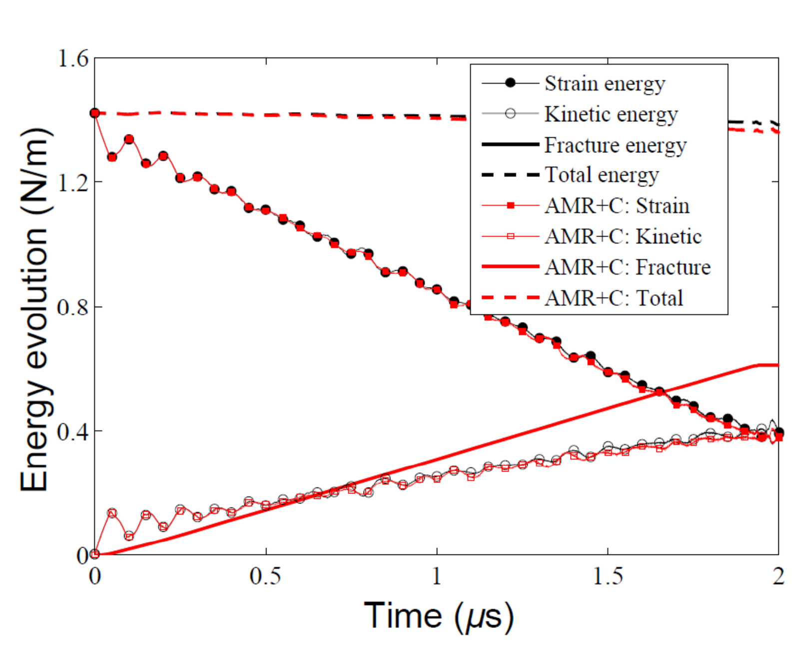
Time to insert cohesive elements scales linearly with mesh size

Mode I Predefined Crack

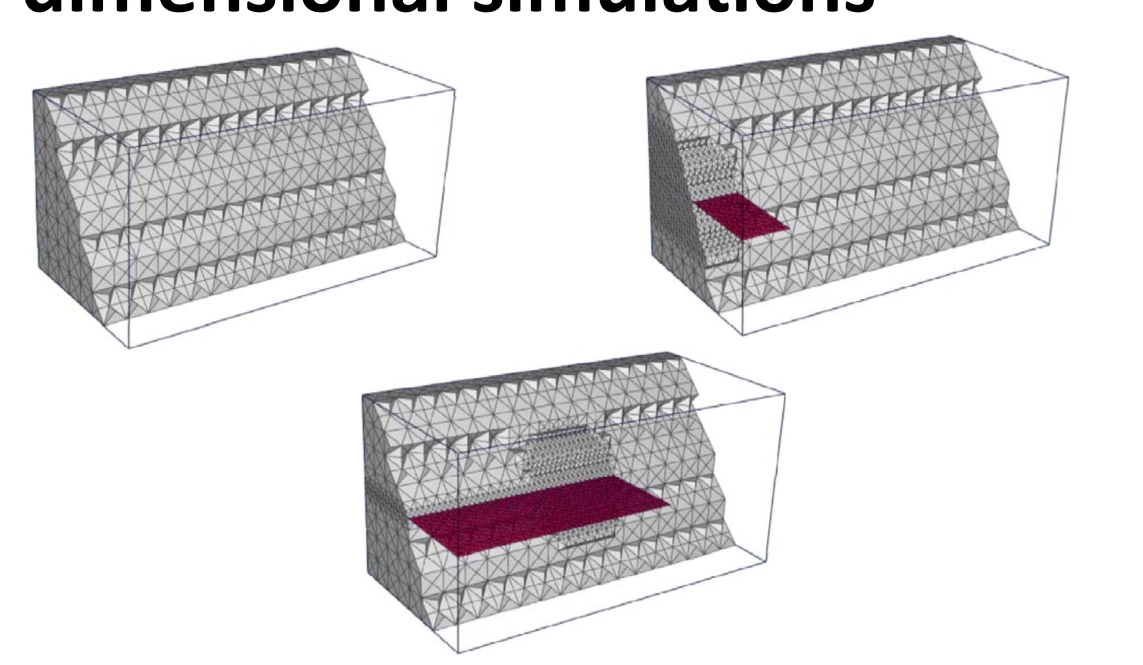
Two dimensional simulation







Data structure support for three dimensional simulations



Conclusions and Extensions

- The potential-based constitutive model with adaptive operators leads to an efficient computational framework to simulate physical phenomena associated with fracture.

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