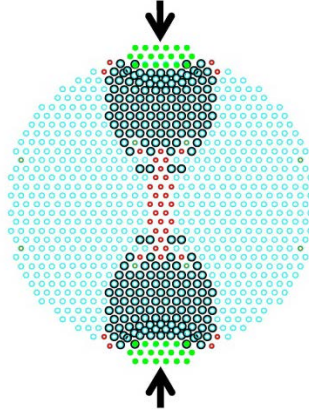


CE598 – “Practical Peridynamics”
Computational Solid Mechanics without the Stress and Strain
4:00 PM-5:15 PM Tuesdays and Thursdays, UNM Main Campus
Fall Semester, 2015

Instructor: Walter Gerstle, Department of Civil Engineering, University of New Mexico

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Course Description: Peridynamics provides an alternative to continuum mechanics. However, peridynamics is more general because it allows cracks to emerge.

Continuum mechanics assumes the material space is a continuous Cartesian real space. In contrast, in this course we assume the material space is a discrete Cartesian integer space, and proceed to develop the state-based peridynamic lattice model (SPLM).

With the SPLM, the forces between neighboring particles are characterized by a force state, T , and the stretches between particles are characterized by a deformation state, Y . The material model arises from a peridynamic function relating the force state to the deformation state. With the SPLM, continuous deformations, elasticity, damage, plasticity, cracks, and fragments can be simulated in a coherent and simple manner.

Much as Timoshenko brought the classical theory of elasticity to the practicing engineers, this course brings peridynamics to modern engineers, who with computers will be aided in solving previously unsolvable problems.

Textbook: Gerstle, W., “Practical Peridynamics: Computational Solid Mechanics without the Stress and Strain”, World Scientific, 2015.

Topics

1. Deformable Solids
 - 1.1 Difficulties with differential equations
 - 1.2 Classical solid mechanics
 - 1.3 Where classical solid mechanics fails
 - 1.4 Introduction to the peridynamic model
 - 1.5 What is a “solid material”?
 - 1.6 Geometric modeling of solids
 - 1.7 Digital aspects of geometric modeling
2. Beginnings of the Theory of Elasticity
 - 2.1 Brief history of solid mechanics
 - 2.2 Navier’s treatise
 - 2.3 Discussion of Navier’s paper
 - 2.4 Cauchy’s treatise
3. Continuum Mechanics
 - 3.1 Newton, vectors, calculus, and continuity
 - 3.2 Vectors and tensors
 - 3.3 Kinematics
 - 3.4 Physical laws of mechanics and thermodynamics
 - 3.5 Traction and stress
 - 3.6 Constitutive relations
 - 3.7 Solving the continuum equations
4. Fracture Mechanics
 - 4.1 Historical overview of fracture mechanics
 - 4.2 Linear elastic fracture mechanics
 - 4.3 Griffith energy criterion
 - 4.4 Mixed-mode fracture propagation criteria
 - 4.5 Fatigue crack propagation
 - 4.6 Nonlinear fracture mechanics
 - 4.7 Computational fracture mechanics
 - 4.8 Conclusions regarding fracture mechanics
5. Bond-Based Continuum Peridynamics
 - 5.1 Introduction to the bond-based peridynamic theory
 - 5.2 Kinematics of the bond-based peridynamic theory

- 5.3 Kinetics of the bond-based peridynamic theory
- 5.4 Restrictions on the pairwise force function, f
- 5.5 Isotropic ordinary bond-based peridynamic model
- 5.6 Elastic bond-based peridynamic models
- 5.7 Relationship between peridynamic traction and stress
- 5.8 Microelasticity under homogeneous deformation
- 5.9 Classical elastic moduli
- 5.10 Boundary conditions
- 5.11 Fracture
- 5.12 Generality of the bond-based peridynamic model
- 5.13 Bond-based micropolar peridynamic model
- 6. Particle Lattice Model For Solids
 - 6.1 Real numbers and continuous functions
 - 6.2 Foundations of solid modeling
 - 6.3 Solid modeling in Euclidean space
 - 6.4 Solid bodies modeled as particle lattices
 - 6.5 Lattice topology
 - 6.6 Computational lattice model for a structure
 - 6.7 Modeling issues
- 7. Elastic Bond-Based Peridynamic Lattice Model
 - 7.1 Linear elastic bond-based lattice models
 - 7.2 Linear elastic regular lattice model
 - 7.3 Linear elastic micropolar lattice model
 - 7.4 Conclusions regarding bond-based lattice models
- 8. State-Based Peridynamic Lattice Model (SPLM)
 - 8.1 Generalizing Navier's theory
 - 8.2 Reasons for state-based peridynamic theory
 - 8.3 Bond-based peridynamic states
 - 8.4 Vector states and tensors
 - 8.5 State fields
 - 8.6 State based peridynamic theory
 - 8.7 Deformation state and state-based constitutive models
 - 8.8 Adaptation of classical material models
- 9. Elastic SPLM
 - 9.1 SPLM stretch and SPLM force
 - 9.2 Relationship between SPLM stretch and strain
 - 9.3 Relationship between SPLM force and stress
 - 9.4 Linear elastic constitutive relation
 - 9.5 Boundary particles
 - 9.6 Uniaxial case
 - 9.7 Plane stress case
 - 9.8 Plane strain case
- 10. Plasticity
 - 10.1 History of Theory of Plasticity
 - 10.2 Continuum Plasticity
 - 10.3 Adaption of classical material models to continuum state-based peridynamic model
 - 10.4 SPLM mobile plasticity models
- 11. Damage
 - 11.1 History of damage mechanics
 - 11.2 Continuum damage mechanics theory
 - 11.3 Damage localization
 - 11.4 Damage model for micropolar peridynamic lattice
 - 11.5 Isotropic SPLM damage mechanics
 - 11.6 Relationship to fracture mechanics
 - 11.7 Damage due to excessive plastic deformation
- 12. Particle Dynamics
 - 12.1 Basic algorithm for explicit particle dynamics
 - 12.2 Critical time step for a single degree of freedom system
 - 12.3 Critical time step in terms of speed of sound
 - 12.4 Damping
- 13. Computational Implementation
 - 13.1 Domain decomposition algorithm
 - 13.2 Design and implementation of pdQ
 - 13.3 Interprocessor communication
 - 13.4 Neighbor lists
 - 13.5 Shuffle: moving particles from cell to cell
 - 13.6 Domain boundary conditions
 - 13.7 Pre- and post-processing
 - 13.8 Computational performance
- 14. Simulation of Reinforced Concrete
 - 14.1 SPLM model for reinforced concrete structures plates
 - 14.2 Particle-level study of SPLM
 - 14.3 Standard concrete cylinder under axial loading
 - 14.4 Simulation of reinforced concrete beams