Data-Driven C-Refinement
A proof-of-concept

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Data-Driven Computational Mechanics [1]

Data-Driven Computational Mechanics (DDCM) is a new paradigm to solve mechanical problems without using a constitutive law. A mechanical problem can be formulated with a set of equations originating from physical principles, such as balance of momentum, and from the geometry of deformation: the compatibility equations. To close the system in the classical paradigm, a constitutive law, linking stress and strain, is employed. In Data-Driven Mechanics, a set of strain-stress datapoints replaces the constitutive law. No model is assumed, the points are used directly and thus no modeling bias or simplification is introduced.

C-refinement

- DDCM is computationally intensive
- Some material behaviors (e.g., metals) can be convincingly described as linear and elastic in the small-strain regime

Idea : Use DDCM only where and when necessary

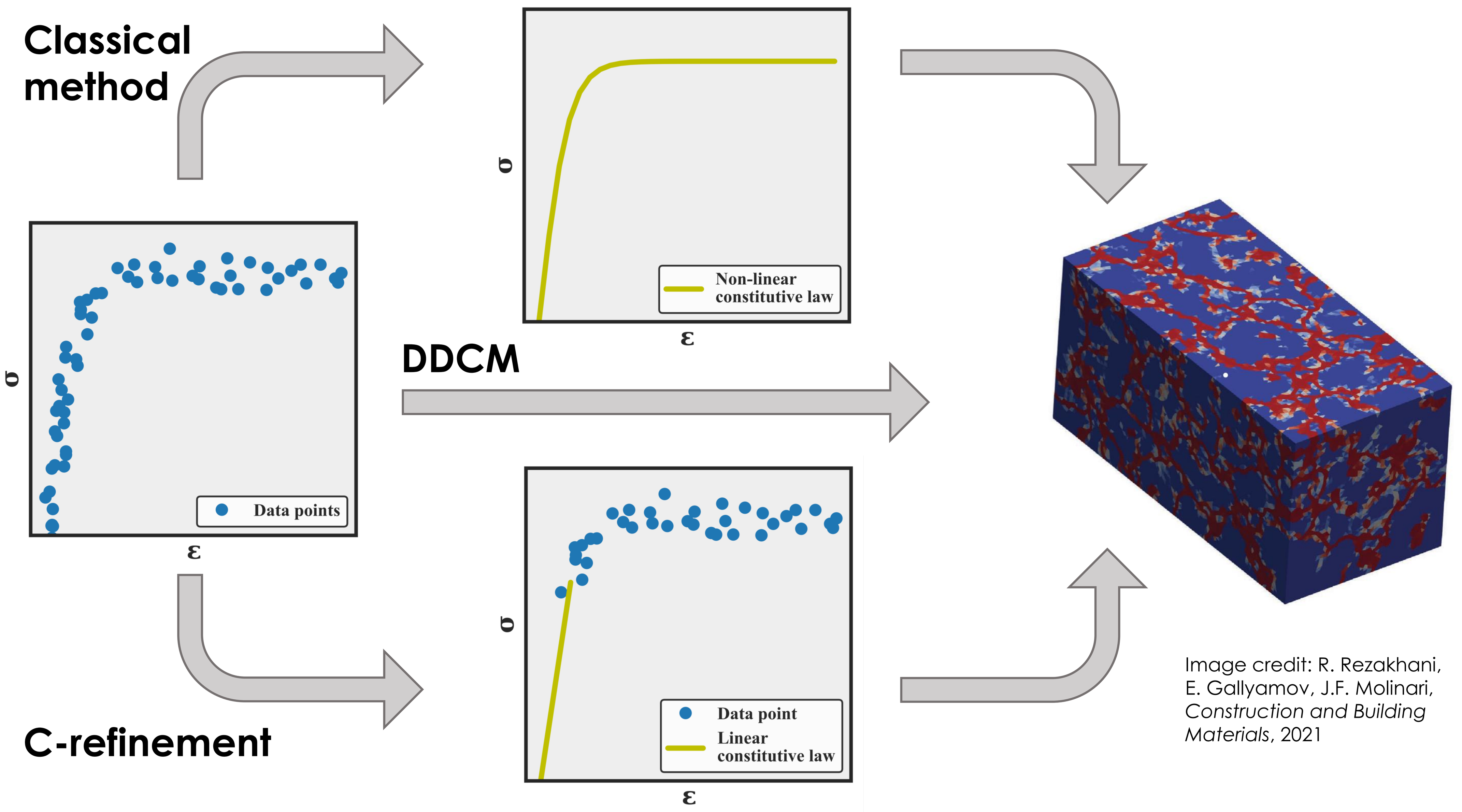


Image credit: R. Rezakhani, E. Gallyamov, J.F. Molinari, *Construction and Building Materials*, 2021

How-to

- Define the linear elastic domain
- Solve with linear elastic FEM
  - Check for elements leaving the elastic domain
  - Switch these elements from FEM to DDCM
  - Use the coupled DDCM/FEM solver [2]
- Iterate until all FEM elements are within the elastic domain

Pros versus non-linear FEM

- No constitutive modeling necessary beyond the linear elastic part
- No iterative non-linear solver: one step solving for the FEM part

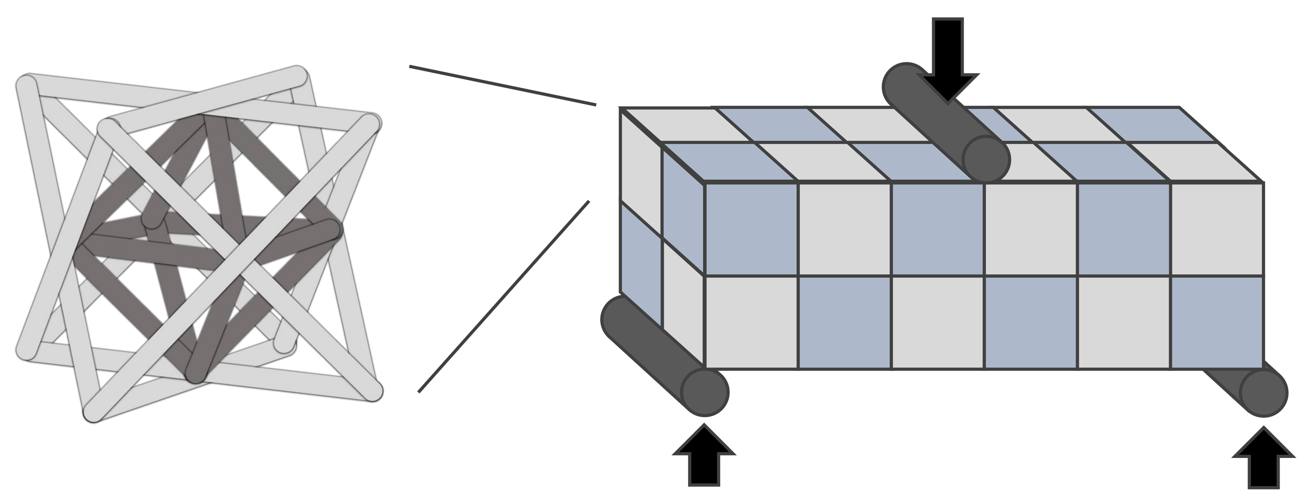
Pros versus DDCM

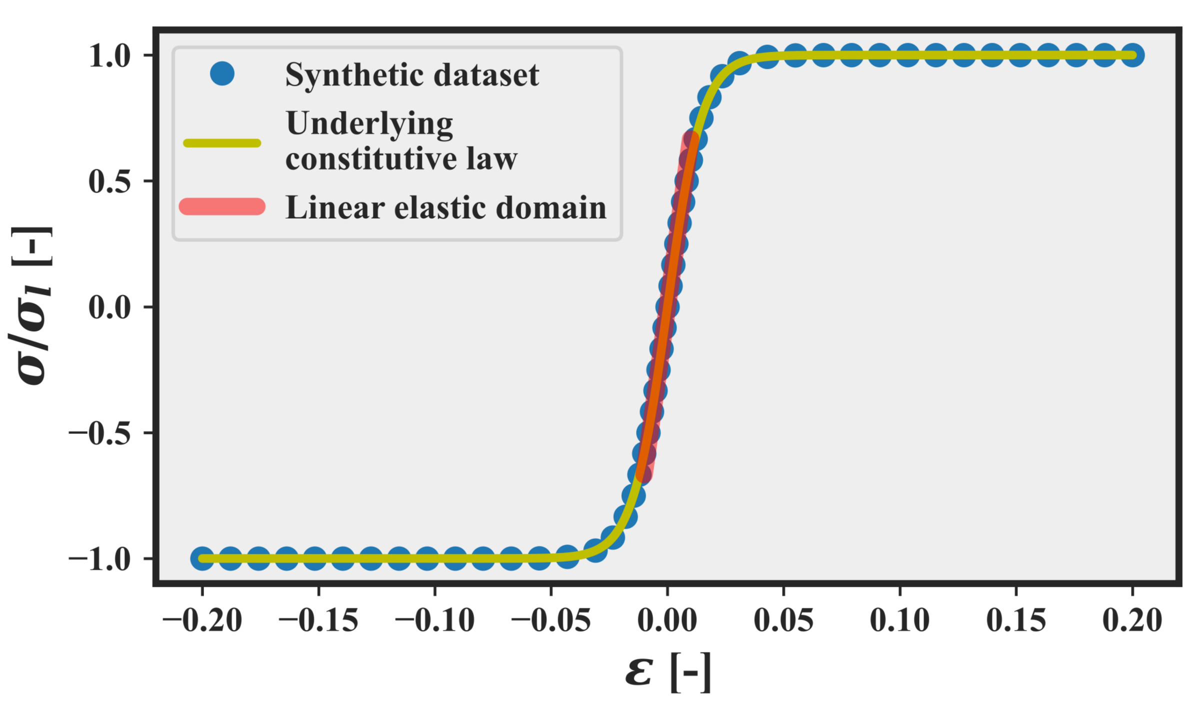
- Faster : the costly data-search step is restricted to DDCM elements
- Reduced stability issues in dynamics

Application to 3-point bending of an octo-truss beam

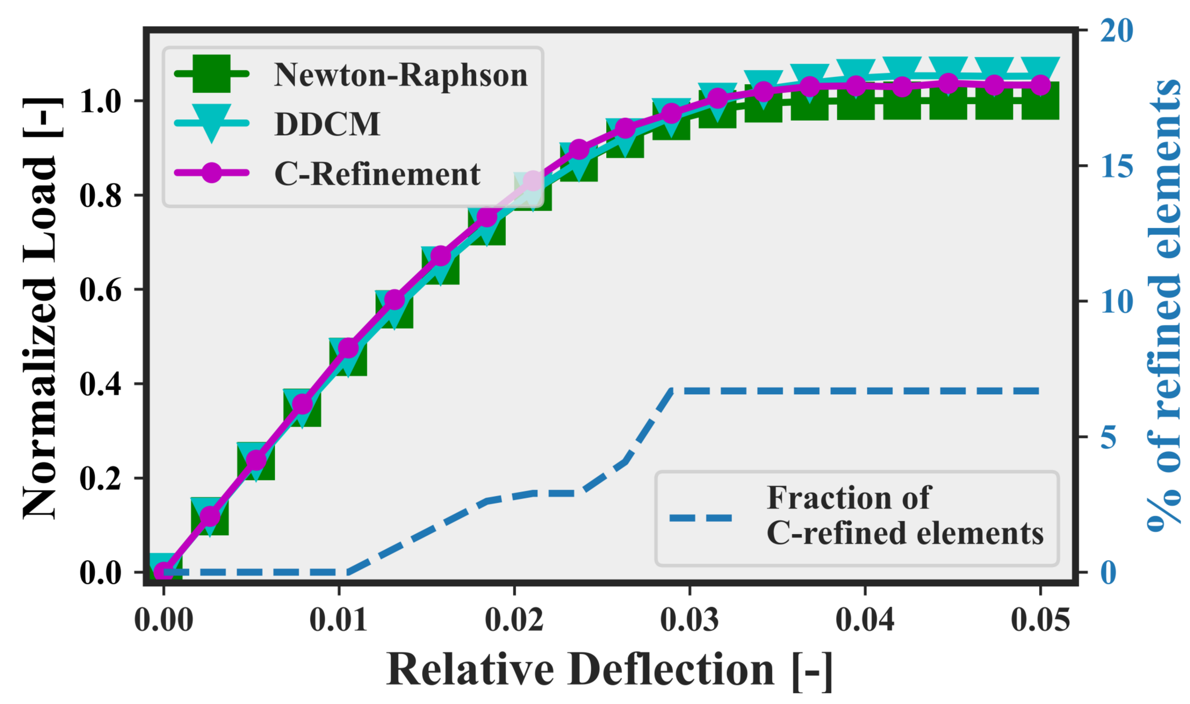
A truss beam composed of 6x2x2 unit octet-trusses [3] is subjected to a load-controlled 3-point bending test. The material behavior is synthetically generated from a hyperbolic tangent. Three solving methods are compared: Newton-Raphson, DDCM and C-refinement.

Octet-truss unit cell used to construct the beam, Each element has unit length and cross-section area and can take only axial effort.

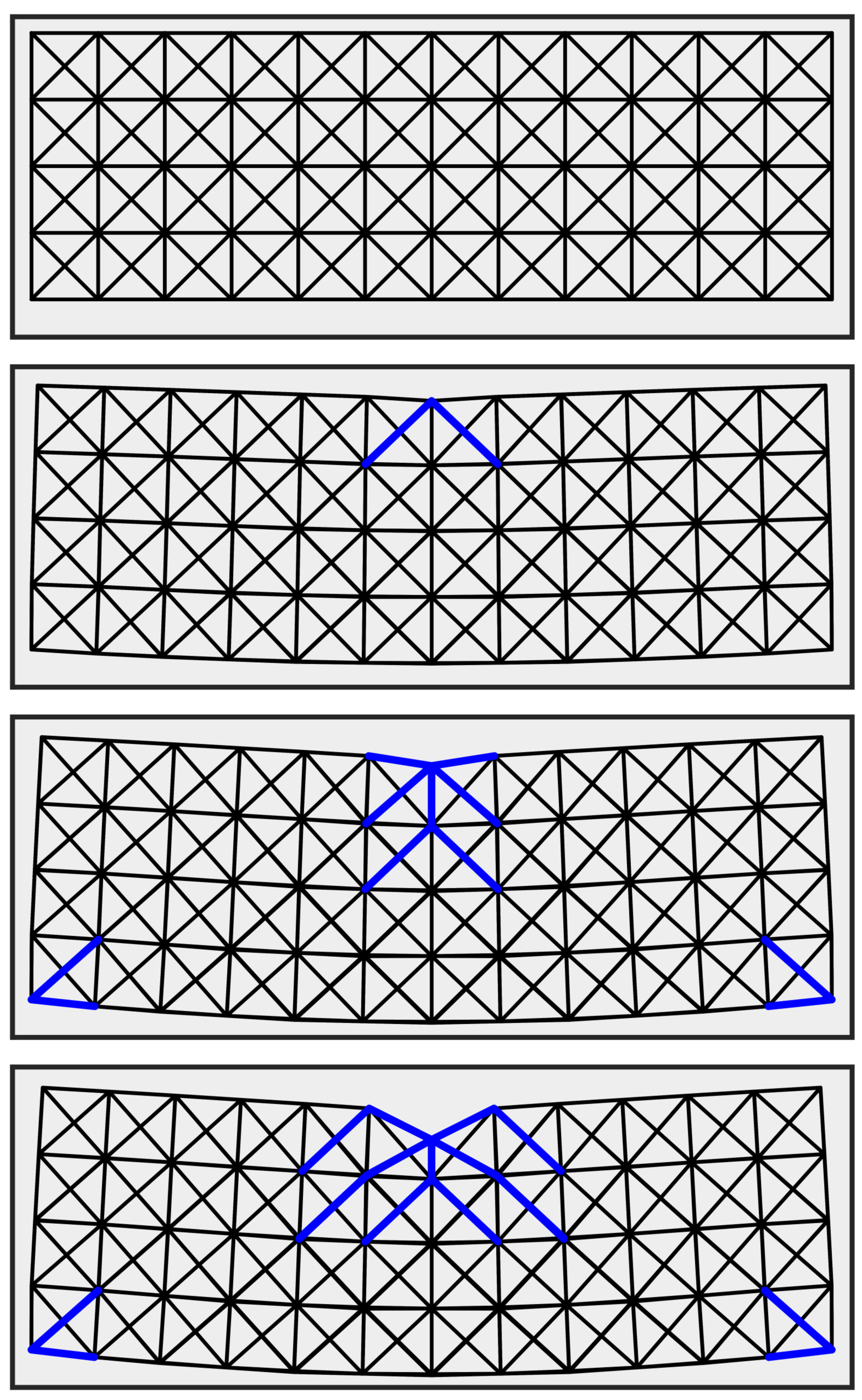




Material behaviors considered. The number of datapoints shown is reduced for legibility: 2700 datapoints are used for the simulations.



Load-deflection curve for the beam for the three tested methods. The dotted blue line is the fraction of elements turned into data-driven ones.



2D projection of truss beam for increasing loading. Blue elements have been turned into data-driven ones.

[1] Kirchdoerfer, T., and M. Ortiz. “Data-Driven Computational Mechanics.” *Computer Methods in Applied Mechanics and Engineering*, 2016
[2] Yang, Jie, Wei Huang, Qun Huang, and Heng Hu. “An Investigation on the Coupling of Data-Driven Computing and Model-Driven Computing.” *Computer Methods in Applied Mechanics and Engineering*, 2022
[3] Deshpande, V. S., N. A. Fleck, and M. F. Ashby. “Effective Properties of the Octet-Truss Lattice Material.” *Journal of the Mechanics and Physics of Solids*, 2001

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