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An efficient composites database construction method for data-driven computing

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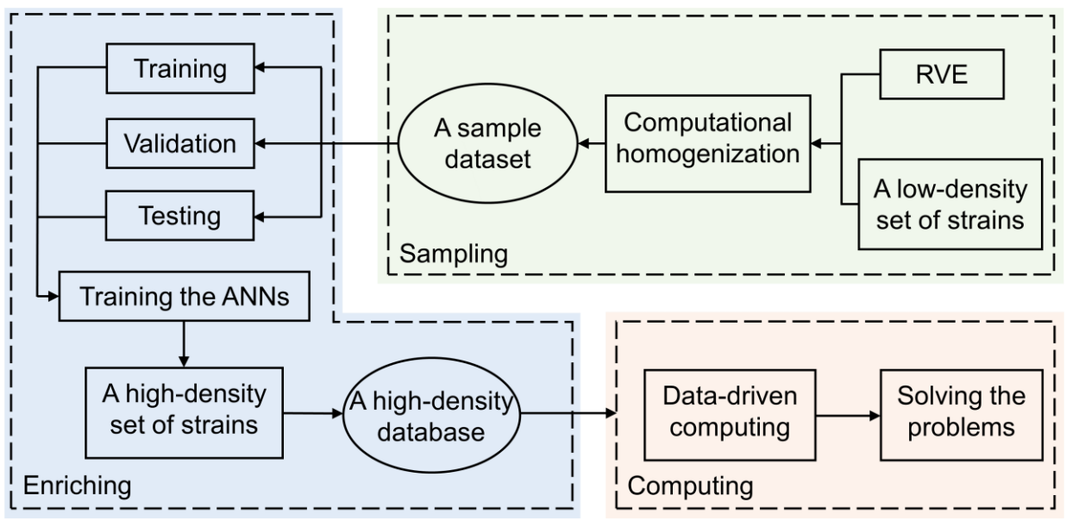
Abstract

A new method combining computational homogenization and the Artificial Neural Network (ANN) is proposed to construct composites database efficiently for data-driven computational mechanics (DDCM). The numerical calculations are performed on the representative volume element (RVE) of composites to collect a small set of high-fidelity data containing stress and strain tensors, which is then enriched using ANN to provide sufficient data for DDCM. To justify the validity and efficiency of the proposed method, a composite plate made of fiber reinforced material is considered. This problem has nonlinearity caused by fiber buckling and plasticity of matrix in the RVE. ANN shows good ability to learn nonlinear relationships between stress and strain from the data collected by computational homogenization, and to generate new data efficiently.

Methodology and context

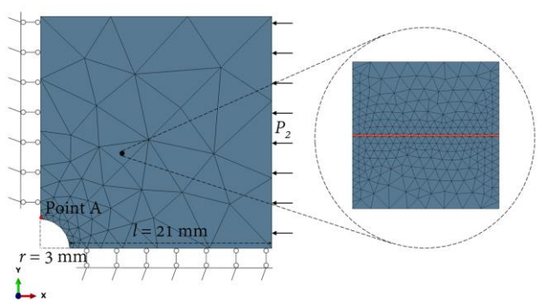
Data-driven computational mechanics (DDCM) [1] uses constitutive data of materials to replace constitutive models in classical computational mechanics, thus avoiding the error and uncertainty arising from the constitutive modeling. However, the constitutive database is often limited or sparse in engineering applications. A method that combines computational homogenization and ANN is presented to construct constitutive database of composites efficiently for DDCM.



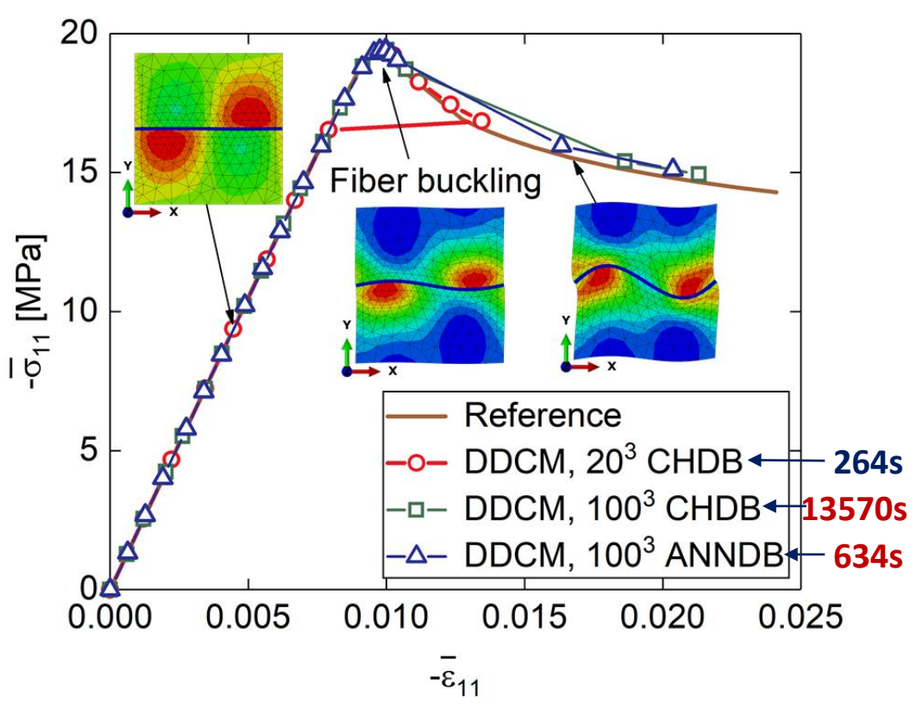
Advantages: this work is expected to uncover the possibility of applying the data generated by artificial intelligence to DDCM in solving mechanical problems of composites.

Results

Instability analysis of composite plate [2]



Nonlinearity due to fiber buckling and plasticity of matrix



Conclusion and perspectives

The proposed method reduces the computational cost of data collection comparing to computational homogenization. Moreover, the accuracy of the DDCM results is greatly increased with the database enriched by the proposed method. Finally, the simulation results also show the possibility of employing the database collected by artificial intelligence to DDCM in solving mechanical problems of composites.

References

[1] Kirchdoerfer T., Ortiz M., Data driven computational mechanics, ***CMAME*** 304 (2016) 81-101.
[2] Liang L., et al., A database construction method for data-driven computational mechanics of composites, ***IJMS***, 249 (2023) 108232.