International Research Training Group IRTG 2657
Computational Mechanics Techniques in High Dimensions

Development of Learning Methods for Controlling Highly Non-Linear Calculations in Structural Mechanics

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Second Cohort – Starting Date: 30.09.2024, CIFRE Project with EDF R&D

Motivation

One of the main mission of Électricité De France (EDF) is to ensure the safety, reliability and integrity of the energy production units, especially amongst the nuclear power plants. Modelisation as well as numerical simulation offer crucial tools for these objectives. EDF develops its own Finite Element Analysis (FEA) open source software *code_aster* and develops more and more complex models to represent non linear processes. One of the issues EDF is facing is moving from research models to engineering models used every day by its design engineers. Indeed, the non linear models are usually very complex and require expert knowlegde for them to be used, which EDF's engineers sometimes do not have.

The aim of this project is to analyse to what extent can learning methods facilitate the use of the non linear models and to develops such tools.

First Inquiries

One of the first issues that arose was regarding the use of arc lengths method within *code_aster*. These methods require a few hyper parameters tuning by the user as well as within the software. For geometrical nonlinearities, Newton's method is commonly used for solving the nonlinear problems. This method is a predictor-corrector method. Several prediction methods are investigated.

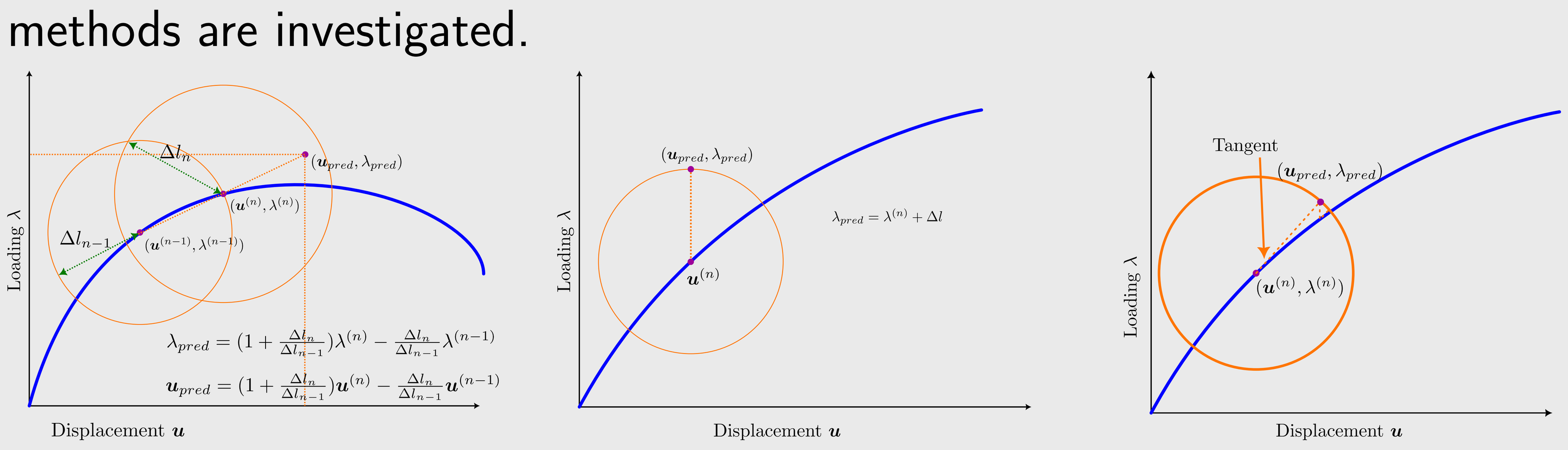

Figure: From left to right: prediction by extrapolation [1], loading prediction, tangent prediction

The cylindrical arc length method [2], which gives back two solution and therefore imposes a choice between two solutions, is used for the correction.

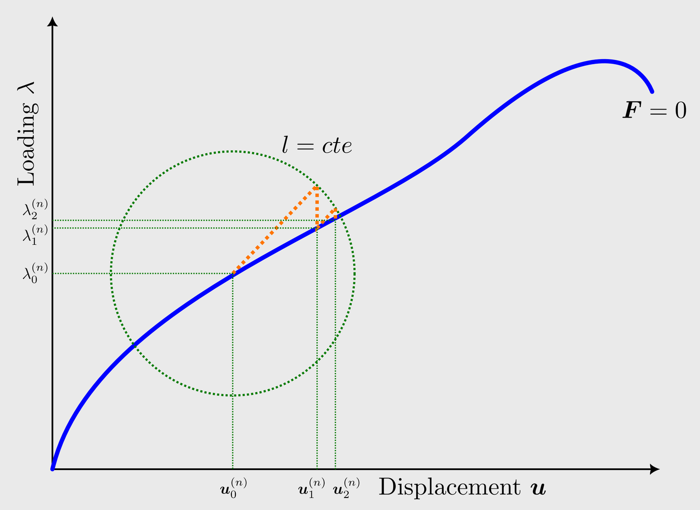

Figure: a) Lee's frame, b) 3 bars in compression

The first part of the project focused on geometrical nonlinearities and investigating where could machine learning (ML) be helpful for their usage.

Test Cases

Three test cases were investigated: Lee's frame as well as 3 bars in compression with two formulations (small strains and finite strains).

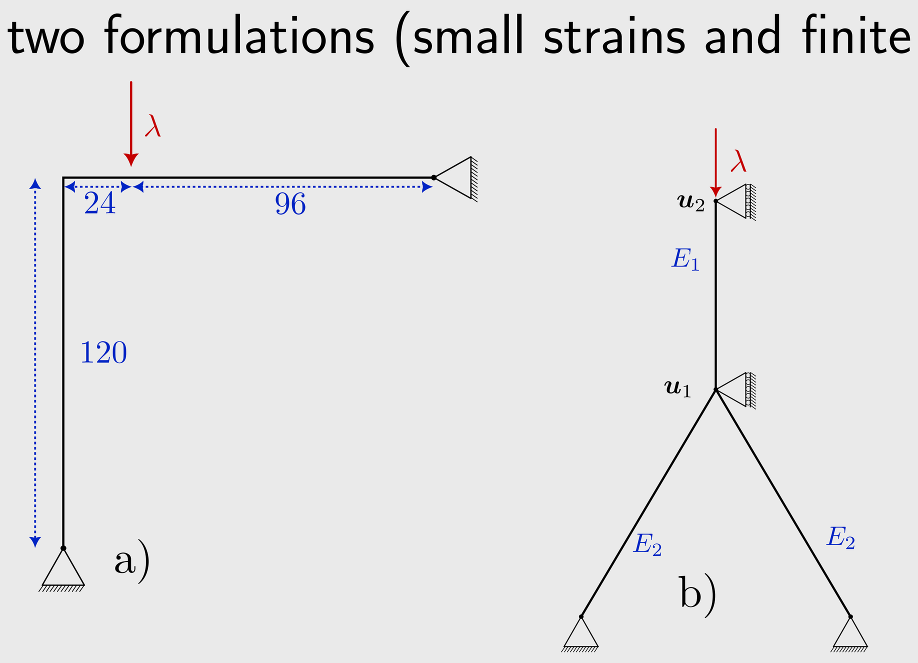

Figure: a) Lee's frame, b) 3 bars in compression

Primary Results

The response curves for these problems are given below

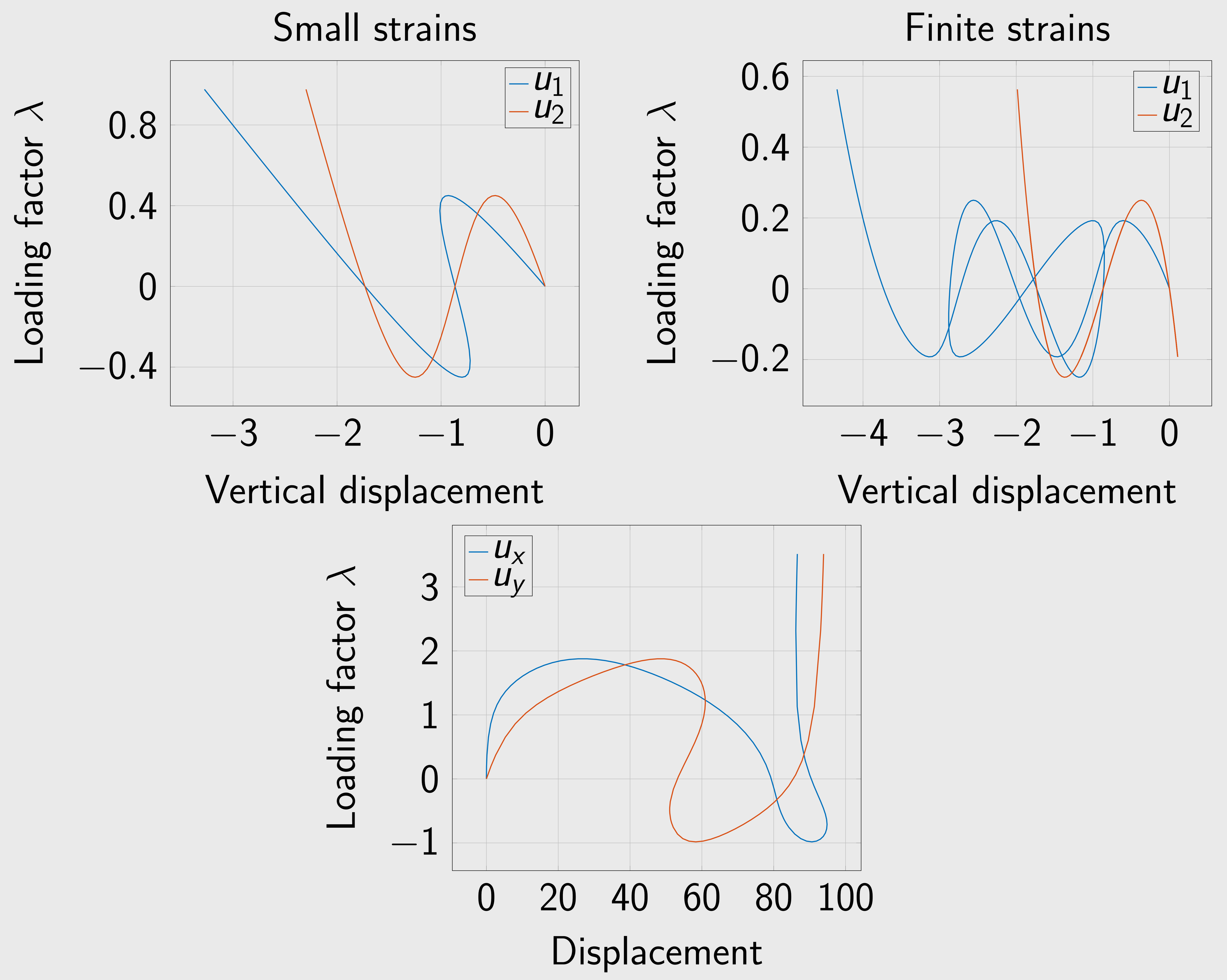

Figure: Loading displacement curves for the test cases

Combining the cylindrical arc length method with the extrapolation prediction method allows for easy simulation of the test cases. This result leads to thinking that ML might not be useful to help for the prediction or the correction phase in this kind of geometrical non linear problems.

Next Steps

For quasistatic nonlinear simulations it is necessary to use pseudo time steps in order to ensure convergence. Several empiric methods exist to adapt the list of instants.For example, the size of the increment is divided in case of non convergence or can be multiplied if there is convergence. Ongoing work is focusing on trying to use reinforcement learning methods [3] for the definition of the list of instants.

Research Environment

Jour fixe meeting within the LMPS research group. Teacher assistant for continuum mechanics. Participated at DTE/AICOMAS conference and at the CSMA Junior workshop.

References

[1] C. Kadapa, "A simple extrapolated predictor for overcoming the starting and tracking issues in the arc-length method for nonlinear structural mechanics," *Engineering Structures*, vol. 234, p. 111 755, 2021.
[2] M. A. Crisfield, "A fast incremental/iterative solution procedure that handles snap-through," *Computers & Structures*, 1981. DOI: 10.1016/0045-7949(81)90108-5.
[3] R. S. Sutton, A. G. Barto, *et al.*, *Reinforcement learning: An introduction*. MIT press Cambridge, 1998, vol. 1.

Funded by Deutsche Forschungsgemeinschaft German Research Foundation