Surrogate-aided quasi-Newton techniques for fluid-structure interaction

Nicolas Delaissé[1,*], Dieter Fauconnier[2,3] and Joris Degroote[1,3]

[1]Department of Electromechanical, Systems and Metal Engineering, Ghent University
Sint-Pietersnieuwstraat 41, 9000 Ghent, Belgium, Nicolas.Delaisse@UGent.be

[2]Department of Electromechanical, Systems and Metal Engineering, Ghent University
Technologiepark Zwijnaarde 46, 9052 Zwijnaarde, Belgium

[3]Flanders Make @ UGent – Core Lab EEDT-MP

Key Words: Quasi-Newton, Coupling Algorithm, Fluid-Structure Interaction, Surrogate Model

ABSTRACT

The partitioned approach towards fluid-structure interaction (FSI) problems is popular because it allows to reuse mature and reliable codes, which are optimized for either fluid or structure. However, in the case of high added-mass the approach may encounter stability problems leading to slow convergence or even divergence. Throughout the years, many techniques have been developed to counteract the destabilizing effect of the added-mass, such as IQN-ILS [1] or IQN-MVJ [2]. These methods all present a coupling algorithm which is based on the quasi-Newton principle: they approximate a (inverse) Jacobian based on input-output pairs, treating the actual solvers as black-boxes.

This pure black box approach is not always desirable, as often some information about the problem is already known or can be determined with limited effort. In this work, the term surrogate model is used to denote this additional information and may take the form of an analytical solver, a coarse-grid solver, a solver which is reduced in dimension, or even the form of solver evaluations at previous time steps. It is shown how a surrogate model can be used to provide both a prediction at the start of each time step and an initial approximation for the Jacobian. The ultimate goal is to limit the number of iterations of the actual solvers, as they represent the main cost. It is, however, essential that the surrogate evaluations are significantly cheaper, such that the overall cost decreases.

Subsequently, the procedure is formalized as the *quasi-Newton method with approximation of the inverse Jacobian from a least-squares model and surrogate model* (IQNI-LS-SM) and it is shown that existing techniques also fit inside this framework. Finally, the performance of this algorithm is evaluated on a typical FSI example using the in-house code coupling code CoCoNuT.

REFERENCES

[1] J. Degroote, K.-J. Bathe and J. Vierendeels. "Performance of a new partitioned procedure versus a monolithic procedure in fluid-structure interaction." *Computers and Structures.*, **87(11-12)**, 793–801, (2009).

[2] F. Lindner, M. Mehl, K. Scheufele and B. Uekermann. "A comparison of various quasi-Newton schemes for partitioned fluid-structure interaction." *6th Int. Conf. on Computational Methods for Coupled Problems in Science and Engineering*, 477–488, (2015).