Acceleration methods for fixed point coupled problems iterations

Isabelle Ramière, Thomas Helfer

Commissariat à l'Énergie Atomique et aux Énergies Alternatives (CEA)
Centre de Cadarache
DEN, DEC, SESC, LSC
F-13108 Saint-Paul-Lez-Durance.
e-mail: isabelle.ramiere@cea.fr, thomas.helfer@cea.fr

ABSTRACT

Fixed point iterations are still the most common approach to dealing with a variety of numerical problems such as coupled problems (multi-physics, domain decomposition,...) or nonlinear problems (electronic structure, heat transfer, nonlinear mechanics, ...). For coupled problems, this partitioning approach has the main advantage to enable the use of efficient numerical solvers dedicated to each physic. However fixed point iterations converge generally only linearly and very slowly. Methods to accelerate fixed point iteration convergence or more generally sequence convergence have been extensively studied since the 1960's. For scalar sequences, the most popular and efficient acceleration method remains the Δ^2 of Aitken. Various vector acceleration algorithms are available in the literature, which often aim at being multi-dimensional generalizations of the Δ^2 method.
In this presentation, we propose and analyze a generic residual-based formulation for accelerating vector sequences [1]. We show that through this formulation, various existing acceleration algorithms for vector sequences are recovered [2] and many other ones can be generated.
The question of the dynamic use of this residual-based transformation during the fixed point iterations for obtaining a online accelerated fixed point method is then raised. We show that two main classes of dynamic iterative algorithms can be derived.
We show the efficiency of such acceleration algorithms on two kinds of tests. First, we compare some of the residual-based acceleration algorithms in the field of nonlinear mechanics. In particular, well-chosen accelerated algorithms combined with a quasi-Newton method based on the elastic operator are prove to be competitive with respect to the standard second-order Newton-Raphson algorithm. Then, we present some numerical results obtained using acceleration techniques on a multi-physics thermal-mechanical-physical chemistral problem derived from the simulation of nuclear fuel behavior [3] and solved thanks a Gauss-Seidel fixed point algorithm.

REFERENCES

[1] Ramière, I, and Helfer, T. *Iterative residual-based vector methods to accelerate fixed point iterations*. Computers and Mathematics with Applications, volume 70 (9), pp. 2210-2226, 2015.

[2] Brezinski, C., and Redivo Zaglia, M., *Extrapolation Methods: Theory and Practice*, North Holland, 1991.

[3] Michel, B., Nonon, C., Sercombe, J., Michel, F., Marelle, V., *Simulation of pellet-cladding interaction with the PLEIADES fuel performance software environment*, Nuclear Technology, volume 182 (2), pp. 124-137, 2013.