Parallelization of non-overlapping domain decomposition methods for non-linear structural dynamics problems

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Structural dynamics is concerned with the behaviour of mechanical structures under application of external forces. These structures are typically modelled as finite element method (FEM) models of substructures coupled via (non-linear) algebraic equations for constraints and friction of the connections. This leads to large matrices with dense blocks of varying size along the diagonal, and blocks loosely connected to few other blocks. The study of structural dynamics allows the integration of NVH (noise, vibration & harshness) concerns in the pre-prototype design phase.

Widely used overlapping domain decomposition such as Schwarz methods require a trade off between multiplicative and additive correction, and thereby between convergence speed and opportunities for parallelisation. In addition, the condition number of the created subproblems depends on the size of the overlap and limits parallel scaling.

In this talk we trace the idea of non-overlapping domain decomposition from the initial use of substructuring to enable FE analysis of problems larger than working memory, to the re-discovery of these schur-complement methods in recent years for distributed computing. [2, 3]

We primarily investigate a classical hybrid MPI + OpenMP and evaluate suitability of a task based approach due to the recursive nature of domain decomposition methods. We present scaling, as well as time- and energy to solution numbers for a typical cluster node, as well as accelerated and non-x86 lower power systems.

References

[1] Domain Decomposition, P. E. Bjorstad , B. Smith , W. Gropp, Cambridge University Press (2004)

[2] Domain Decomposition Methods for Distributed Computing, J. Kruis

[3] Nonlinear Preconditioning: How to use a Nonlinear Schwarz Method to Precondition Newton's Method, V. Dolean, M.J. Gander, F. Kwok, R. Masson, W. Kheriji