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Extension of the GEMSEO MDO library to a MPI parallel coupled adjoint capability

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Multidisciplinary Design Optimization (MDO) is usually expressed as the search for the best compromise between multiple disciplines. In design problems, various interactions occur between the involved disciplines, and handling properly these interactions is a key enabler of MDO techniques for solving such problems. In particular, Multi-Disciplinary Analysis (MDA) are necessary to compute the equilibrium state between strongly coupled disciplines. In this case, the adjoint method enables to compute the derivatives of the objective function at a cost independent of the design space dimension.

The disciplinary codes, such as Computational Fluid Dynamics (CFD) or Computation Structural Mechanics (CSM) software, are typically running in parallel on a large number of cores. Also, the exchanged coupling vectors may be very large (> $1e^{+6}$ elements) and may be distributed over the MPI ranks. In a MDA, the time needed to transfer the coupling vectors between the parallel disciplines can be very important if the data have to be written and read through the disk. Also, at the optimizer stage, it may not be possible to assemble and to solve the coupled-adjoint system to get the total derivatives in an acceptable restitution time. For large applications, these characteristics may lead to bottlenecks and large latencies, thus impeding the use of MDO in an industrial context. In order to tackle these limitations and to enhance the efficiency of adjoint-based MDO processes involving parallel disciplines, GEMSEO [1] has been extended to support parallel MPI disciplines by using parallel data structures from the PETSc library. It enables efficient and reconfigurable data transfers between the parallel disciplines through MPI exchanges. Also, the MDA and the coupled-adjoint system are solved in parallel using the PETSc linear algebra functions. For the later, Krylov subspace solvers and block matrix-vector products are used to solve the adjoint system in order to avoid assembling the full adjoint matrix.

The results show the ability to perform a MDO with GEMSEO and two strongly coupled parallel disciplines implemented with bitpit. This test case also enables to benchmark the current implementation in terms of time and memory consumption in a HPC environment. It particularly shows that the overheads related to the transfer of data between the disciplines using MPI exchanges are at least one order of magnitude lower than using the disk.

REFERENCES

[1] F. Gallard et al., GEMS: A Python Library for Automation of Multidisciplinary Design Optimization Process Generation. *AIAA Scitech 2018*, AIAA 2018-0657, 2018.
[2] bitpit library - https://optimad.github.io/bitpit/

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