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The iPGDZ$^+$ Technique for Compressing Primal Solution Time-series in Unsteady Adjoint - Applications & Assessment

A.-S.I. Margetis[a,1,*], **E.M. Papoutsis-Kiachagias**[a,2] **and K.C. Giannakoglou**[a,3]

[1] PhD Student, amargetis@mail.ntua.gr
[2] Postdoctoral Researcher, vpapout@mail.ntua.gr
[3] Professor, kgianna@mail.ntua.gr and http://velos0.ltt.mech.ntua.gr/research/

[a] National Technical University of Athens, School of Mechanical Engineering,
Parallel CFD & Optimization Unit, 15780 Athens, Greece

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Gradient-based optimization for large-scale unsteady problems, in which gradients are computed using unsteady adjoint, may suffer from significant storage requirements since the backward in time integration of the adjoint equations requires the previously computed instantaneous primal solutions (flow fields, herein) to be available at each time-step. If storage is avoided and re-computations are used instead, a significantly longer computational time is expected, which is not preferable either. A middle-ground solution is check-pointing which reduces the memory footprint of the optimization with a controllable CPU cost overhead due to a few re-computations. This paper presents and assesses a Compressed Coarse-grained Check-Pointing (*3CP*) strategy, by combining check-pointing and lossy compression performed using the iPGDZ$^+$ compression algorithm, proposed by the group of authors in [1]. For maximum efficiency, the time-history of the primal solution is partitioned into consecutive time-windows, a sub-set of which is stored in compressed form. Within each time-window, flow field snapshots are compressed using the incremental Proper Generalized Decomposition (iPGD) algorithm. Its outcome is lossly compressed using the ZFP algorithm and, then, the resulting ZFP stream is losslessly recompressed using Zlib. Everything has been implemented within OpenFOAM, which is used to solve the flow and adjoint equations and conduct the optimization and assessed in aerodynamic shape optimization problems including an automotive application. By properly tuning the iPGDZ$^+$, a memory reduction by 2 to 3 orders of magnitude can be enjoyed, while the sensitivity derivatives and the optimal solution are practically unaffected. Effectiveness in data reduction, computational cost and representation accuracy are compared with "standard" binomial check-pointing. The iPGDZ$^+$ can be applied to any scientific area governed by unsteady PDEs, for which the adjoint method is used.

REFERENCES

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