Check-Pointing & Lossy Compression in Unsteady Adjoint-based Optimization in Fluid Mechanics

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In fluid mechanics, the unsteady adjoint method used in gradient-based optimization in large-scale problems 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) to be available at each time-step. Nowadays, as a means to reduce storage, binomial check-pointing[1] is in widespread use. This can reduce the memory footprint of the optimization with a minimum possible computational overhead, thanks to the optimal distribution of check-points within the time-horizon. In this paper, a challenging alternative is presented.

The basic idea is that, once computed, each instantaneous flow field can be lossly compressed using ZFP[2] and, then, the resulting ZFP stream can losslessly be re-compressed using the Zlib compression library. To profit from the advantages of check-pointing, we are proposing an efficient combination of compression and check-pointing. This allows more check-points to be retained in the available memory, reducing flow re-evaluations. Everything has been implemented within OpenFOAM, which is used to solve the flow and adjoint equations[3] and conduct the optimization and assessed in aerodynamic shape optimization problems including an automotive application. The memory footprint of each check-point can be reduced by 1 to 2 orders of magnitude[4], while the sensitivity derivatives and the optimal solution are practically unaffected by lossy compression. Effectiveness in data reduction, computational cost and representation accuracy are compared with "standard" binomial check-pointing, which is the standard approach in an industrial environment. The proposed technique can be applied to any other flow model governed by unsteady PDEs, for which the (continuous or discrete) adjoint method is used, on structured or unstructured computational grids.

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