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A statistical approach for optimising HPC costs in high-fidelity CFD simulations with OpenFOAM

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High-fidelity CFD refers to the class of methods (e.g. LES, DES) that resolve turbulent flow fluctuations directly, rather than representing their time-averaged effect through heuristic models (RANS). As the name implies, such methods give more reliable predictions than steady-state approaches. This benefit, however, comes at a cost of significantly increased computational effort.

The unsteady nature of high-fidelity simulations furthermore confronts the user with additional questions: At what point has the arbitrary initialisation field been "forgotten" and a statistically steady state reached? Once a steady state is established, for how long must a simulation be run to achieve sufficiently accurate estimates of the mean and other statistics? An algorithm to answer these two questions, named Meancalc [1], has recently been released as a SaaS offering hosted in the cloud. Figure 1 gives an impression of Meancalc's capabilities for an example automotive CFD time history.

The talk will focus on an interface between Meancalc and OpenFOAM that allows a simulation to be controlled automatically at run-time based on Meancalc's statistical assessments. The user selects the time histories to be evaluated (e.g. integral force coefficients, flow-field probes) and specifies the statistical accuracy sought (e.g. "95% confidence on mean drag coefficient to within 5 counts"). This novel functionality enables HPC resource usage to be optimised, since simulations are only run for as long as needed to achieve the required statistical convergence. At the same time, the insight gained ensures that robust decisions are made on the basis of simulation results (e.g. allowing true differences between simulations to be separated from statistical noise). As well as cost optimisation, the approach therefore delivers a significant contribution to quality assurance. The functionality will be validated and demonstrated for an analysis of time traces from over 1000 automotive CFD simulations provided by Volkswagen.

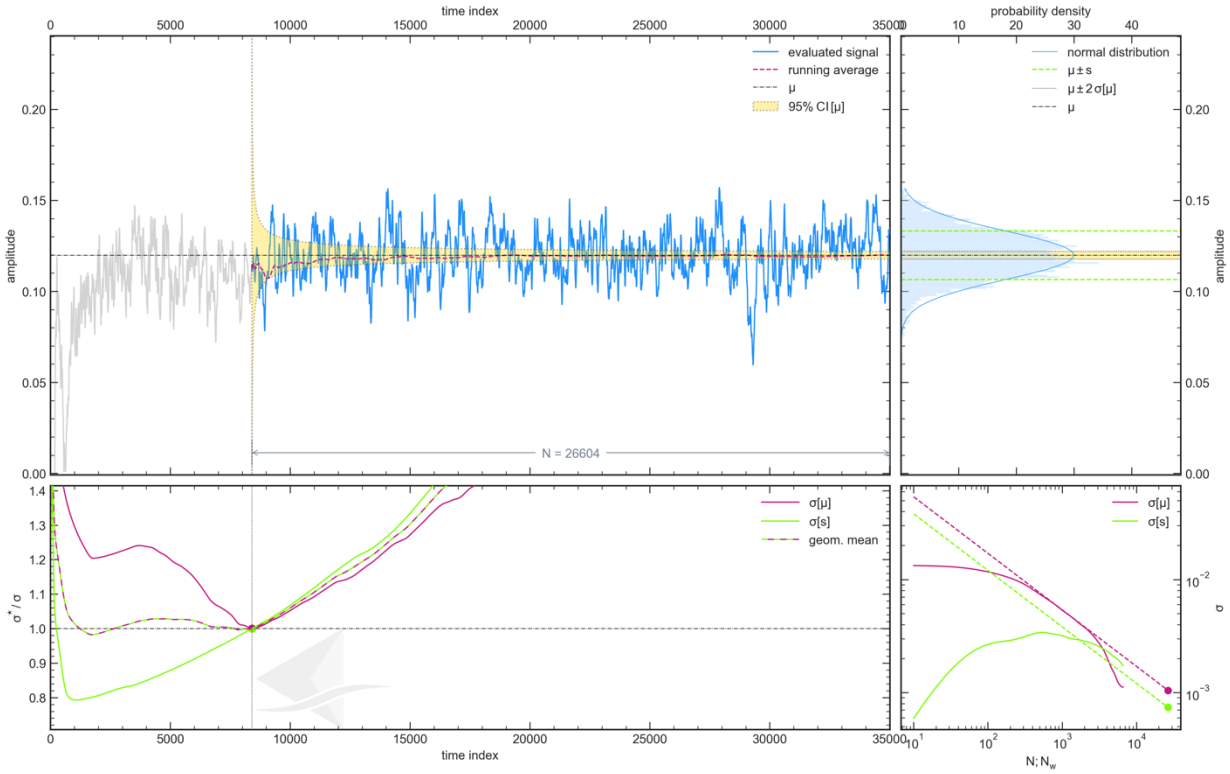

Figure 1: Output of the Meancalc web GUI for an example force coefficient time history from a high-fidelity CFD simulation (automotive aerodynamics test case). The upper left pane shows the entire time trace with the detected transient-free portion (blue) and development of the 95% confidence interval around the mean value (yellow shaded region).

References

[1]. Mockett, C., Knacke, T., & Thiele, F., "Detection of initial transient and estimation of statistical error in time-resolved turbulent flow data", ETMM8 N147, 2010. *[link to PDF]*