Hardware-efficient, Parallelized Optimization with COMSOL Multiphysics® and MATLAB®

T. Frommelt[1], R. Gutser[1]

[1]SGL Carbon GmbH, Meitingen, Germany

Abstract

The power dissipation of processors rises exponentially with clocking frequency. Around 2004, the power limit was reached and lead to a paradigm change in processor development [1]. Instead of higher speed by higher clocking frequency, chip manufacturers continuously increase the number of cores per processor at rather constant clocking frequency. In order to utilize such hardware, simulation software like COMSOL Multiphysics® includes parallelized solvers like MUMPS that provide multi-threading. Yet, splitting up a simulation onto several cores requires more memory and the duration of a multi-threaded simulation is not decreased ideally by far (Fig. 1). For single simulations and large models, this technique is without alternative but for optimization particularly of smaller models an alternative approach matches today's hardware architecture better.

Instead of speeding up the simulation of the forward problem for a serial optimizer by multi-threading, we implemented a parallelized, nature-inspired optimizer LHSOpt (Latin Hypercube Sampling Optimizer) in MATLAB®. In each iteration, latin hypercube sampling is employed to determine an evenly distributed population using the best design as a center point (Fig. 2a). Each design is treated by a single-threaded simulation and the best among all designs is the center point for the next iteration (Fig. 2b). The COMSOL Multiphysics® license model allows for the simultaneous operation of several COMSOL servers. Each of these COMSOL servers acts as an independent worker which can run single-threaded by addressing it to one particular core (see Fig. 3). The exchange of design and result data is handled on a shared directory.

In this study, we benchmark both approaches with a routine geometry optimization of an electro-thermal model: Positioning of parts in an industrial Acheson graphitization furnace (Fig. 4). A theoretical factor 3 for speed-up by single-threading was determined by performance runs on a representative set of designs. Considering the total duration of an optimization, LHSOpt already achieves a speed-up by a factor 1.5 to 2, as compared to the serial optimizer fminsearch (Nelder-Mead-Simplex algorithm). Moreover, tests showed that LHSOpt is not sensitive to the starting point, which is a well-known advantage of population-based optimizers.

The flexible license model of COMSOL Multiphysics® enables the user to choose between multi- and single-threading, depending on the ratio of model demands and existing hardware resources: Large models may benefit from multi-threaded, serial optimization while small models work out best with single-threaded, parallelized optimization.

Reference

[1]: Laurie J. Flynn: Intel Halts Development of 2 New Microprocessors. New York Times, May 8, 2004.

Figures used in the abstract

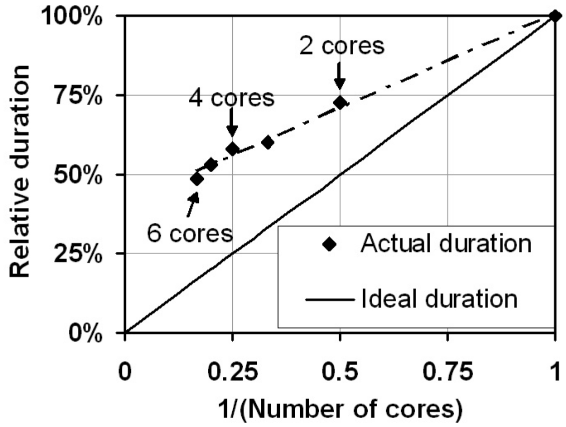

Figure 1: Relative duration of a multi-threaded electro-thermal simulation with respect to the single-threaded reference.

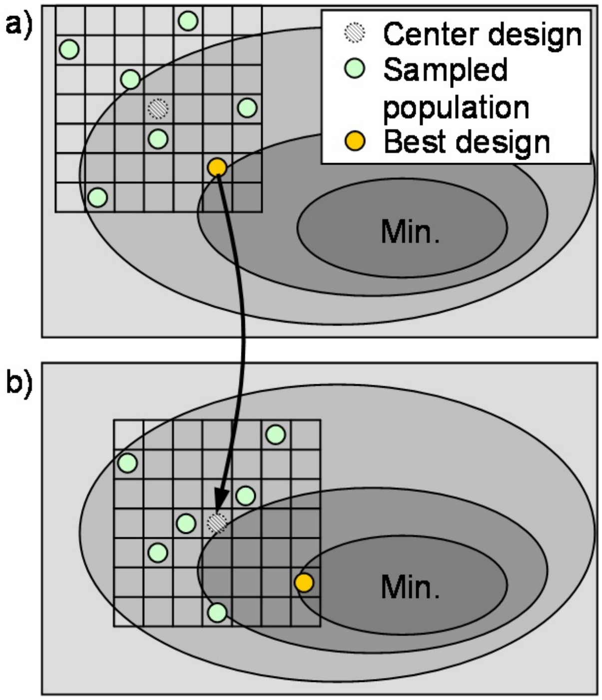

Figure 2: a) Latin hypercube sampling around a center design, b) best design is the center design of the next iteration.

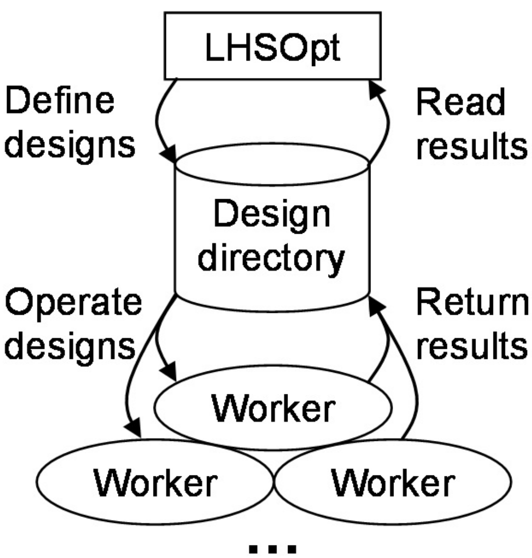

Figure 3: Independent workers (Comsol servers) operate in parallel the designs which are defined by the optimizer LHSOpt.

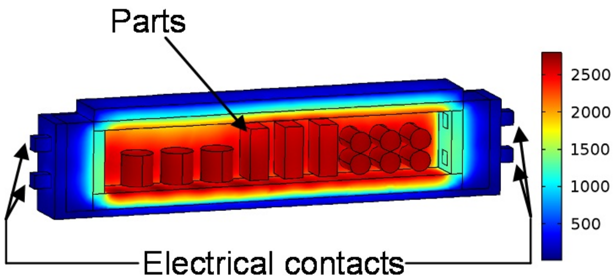

Figure 4: Temperature distribution in an industrial Acheson graphitization furnace. The conductive packing media is hidden to show the parts.