Technische Universität Braunschweig

Graduiertenkolleg 2075
Modelle für die Beschreibung der Zustandsänderung
bei Alterung von Baustoffen

Kompaktkurs im GRK 2075

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Introduction to the Lattice Boltzmann method

Mittwoch, 01.06.2016, 09.45 - 11.15 Uhr und
Donnerstag, 02.06.2016, 09.45 - 11.15 Uhr
Institut für Wissenschaftliches Rechnen, Raum 812
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The perhaps most important criterion for success of any computational method in the future is its scalability. Scalability means that the cost of solving a problem grows slowly with the complexity of the problem. It also means that the ability to harvest the power of the computers of the future must not be limited by some intrinsic feature of the model.

It is very likely that future computers will have the following characteristics: Compared to contemporary computers the number of processors that run in parallel will increase. Compared to contemporary computers the cost of communication either between processors or between one processor and its memory and the cost of arithmetic operations will increase. It is therefore imperative for designing numerical software for the future to minimize the serial part of the model and to minimize communication, potentially at the cost of more arithmetic operations.

In the broad field of computational fluid dynamics, there are in particular two commonly applied modelling concepts that act as obstacles for scalability. These are the assumption of strict incompressibility and the application of implicit time marching methods. While it is fair to say that these two concepts can provide tremendous simplifications and accelerate the simulations significantly in some cases, it is equally fair to say that the performance of implicit methods scale very unfavorable with the complexity and the size of the problem. In highly complex (i.e. fully turbulent) cases the bruit force approach turns out to be more efficient than any clever attempt to simplify something that cannot be simplified.

In the lattice Boltzmann method the physical problem of fluid flow (or other transport problems) is directly stated in form of an algorithm without the detour of discretizing a transport equation. This unconventional approach eliminates some bottlenecks of conventional computational fluid dynamics. For example, the incompressibility as a constraint looks innocent on paper but implies the instantaneous coupling of all degrees of freedom. This major obstacle to scalability is circumvented in the lattice Boltzmann method by a weak (asymptotically small) compressibility.

While the lattice Boltzmann method originated as an algorithmic description of a physical law, in contrast to other such algorithms (i.e. particles methods), the lattice Boltzmann method also lends itself to asymptotic analysis and the equivalent partial differential equations are easily obtained analytically. Consequently, the convergence order of the method can be rigorously proofed and the method can be analytically optimized.

This short lecture series will introduce the lattice Boltzmann algorithm and will discuss relevant variants of the method. We will also discuss the asymptotic analysis of the method and the derivation of equivalent partial differential equations and truncation errors. These methods are also useful for the analysis of other numerical methods.