Lothar-Collatz-Seminar

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Complexity Blowup for Solutions of the Laplace and the Diffusion Equation

Abstract:

Digital computers have become an integral part of modern society. The development of the modern computer can be traced back to Alan Turing's introduction of the Turing machine in 1936. In his seminal work "On Computable Numbers," Turing also identified the limitations of the Turing machine, which are indicative of the constraints faced by digital computers in general. In this presentation, we aim to highlight some of these boundaries as examples. Specifically, we show that for a certain class of initial-boundary value problems of the Laplace and the diffusion equation, the solution operator is $\#P$-complete in the sense that it maps polynomial-time computable functions to polynomial-time computable functions if and only if $FP = \#P$. Consequently, there exists polynomial-time (Turing) computable input data such that the solution is not polynomial-time computable, unless $FP = \#P$. In this case, we can, in general, not simulate the solution of the Laplace or the diffusion equation on a digital computer without having a complexity blowup, i.e., the computation time for obtaining an approximation of the solution with up to a finite number of significant digits grows non-polynomially in the number of digits. This inherent complexity persists regardless of the numerical method employed to solve the differential equation.

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