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FAKULTÄT FÜR MATHEMATIK
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Einladung zur öffentlichen Defensio

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Thema der Dissertation

Numerical Solution of the Acoustic Wave Equation in the Time Domain

Abstract:
In this dissertation, we develop and apply stable and efficient numerical methods for the linear acoustic wave equation in the time domain. Our work explores two main approaches: space—time isogeometric discretizations in Part I, and QTT-structured numerical methods in Part II.
The isogeometric method (Isogeometric Analysis, IGA) is a Galerkin method that uses spline functions, or their generalizations, to parametrize the physical domain and approximate the solution of the corresponding Partial Differential Equation (PDE). In space—time IGA for time-dependent PDEs, spline functions define the discrete spaces that live on a mesh of space *and* time. In Part I of the present work, we introduce an unconditionally stable space—time IGA discretization for the linear acoustic wave equation in the standard second-order-in-time formulation. The unconditional stability is achieved by adding non-consistent penalty terms to the underlying bilinear form. Extensive numerical testing on a wide range of wave propagation problems validates the performance of the method. To address the stability analysis, we study the properties of the conditioning behaviour of a family of matrices associated with the time discretization. For an arbitrary spline degree, we derive explicit, sharp estimates of both the CFL condition required in the unstabilized case and the penalty term that minimizes the consistency error in the stabilized setting. Finally, we devise a space—time IGA discretization for the wave equation based on a first-order-in-time formulation. In contrast with the second-order-in-time formulation, this method showcases unconditional stability without the need for stabilization terms, as demonstrated in several numerical experiments.
The Quantized Tensor Train (QTT) decomposition is an emerging method to enhance the efficiency of simple low-order Finite Element Methods (FEMs). In Part II of this work, we leverage the QTT decomposition to propose a scalable numerical method for the one-

dimensional, homogeneous acoustic wave equation in the time domain. We start from the first-order-in-time formulation already considered in Part I. This problem is discretized with QTT-compressed piecewise linear FEM combined with implicit Gauss—Legendre Runge—Kutta (GLRK) time integrators. The use of GLRK integrators ensures unconditional stability and energy conservation, and the QTT-based complexity reduction allows us to use mesh size up to 2^{-15} at each time step. Numerical tests validate the performance of the method. To the best of our knowledge, this work provides the first QTT-structured discretization of the time-dependent acoustic wave equation.

Prüfungssenat

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Prof. Dr. Lars Grasedyck
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Zeit und Ort

Freitag, 21. Februar 2025, 10:30 Uhr

Online:

> https://univienna.zoom.us/j/61877164752?pwd=ynCz998D6trvpGcJepR1eynPgXRcOG.1
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