ALPEN-ADRIA UNIVERSITÄT KLAGENFURT

Invitation to the Defense

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"A First Order in Time Formulation for Nonlinear Acoustics: Modeling, Analysis, and Simulation"

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Abstract

This thesis derives, analyzes, and simulates a first order in time formulation for nonlinear acoustics. While the literature contains extensive results for second order in time formulations in nonlinear acoustics and for first order in time formulations in linear acoustics, this work fills a gap by establishing a first order in time framework for the nonlinear setting. We begin by laying out the modeling foundations of nonlinear acoustics, deriving the Navier–Stokes–Fourier system from balance laws and thermodynamic principles. Under standard assumptions used in nonlinear acoustics, such as the small amplitude approximation and the substitution corollary, we then derive a first order in time model that contains classical models from nonlinear acoustics, such as Westervelt's and Kuznetsov's equations, as special cases. For the analytical part, we first consider the system with homogeneous Dirichlet boundary conditions and prove global in time well-posedness as well as exponential decay under suitable smallness assumptions on the data. To tackle the nonlinearities, we use a fixed point argument in the form of the Newton–Kantorovich theorem in abstract Banach spaces. We then extend these results to less regular data and to nonhomogeneous boundary

conditions, exploiting the parabolic structure of the first order formulation, and include Neumann and Lions/Hodge boundary conditions.
For the numerical analysis, we employ a space-time discontinuous Galerkin method constructed via the theory of symmetric Friedrichs systems and the interior penalty method. We establish stability and convergence rates in an appropriate norm. Our implementation features parallel execution and p-adaptivity. Numerical experiments in two spatial dimensions confirm the predicted convergence rates and demonstrate the effectiveness and accuracy of the method. They also capture characteristic wave phenomena of nonlinear acoustics, providing physical validation of the model. In summary, this work presents a complete pipeline, derivation, well-posedness analysis, and numerical simulation, for a physically relevant alternative model suitable for applications, and it identifies several promising directions for future research.

Elena Resmerita and the Department of Mathematics look forward to seeing you at the talk!