Friedrich-Alexander-Universität
Technische Fakultät

Seminar über Fragen der Mechanik

zu folgendem Vortrag wird herzlich eingeladen

Mittwoch, 18.10.2023, 10:00 Uhr

Immerwahrstr. 1, Raum 01.025 / https://fau.zoom.us/j/97303812645

Controlling nonlinear elastic systems governed by hyperbolic PDEs

M.Sc. Timo Ströhle

Institute of Mechanics, Karlsruhe Institute of Technology

How does a flexible body have to be excited on a given boundary, such that the motion on a disjunct boundary can be prescribed? This seemingly simple question will be pursued in this talk. In this context we aim to restrict ourself to systems that are governed by quasi-linear hyperbolic partial differential equations subjected to time- varying *Dirichlet* boundary conditions that are enforced by unknown, spatially disjunct, hence non-collocated *Neumann* boundary conditions.

Commonly, initial boundary value problems that occur in non-linear structural dynamics are solved by applying sequential space-time discretization methods. This approach is therefore typically based on a discretization in space by means of finite elements, followed by an appropriate discretization in time mostly based on finite differences. A brief survey of this type of sequential space-time integration methods for the initial boundary value problem at hand, is given first in context of the direct dynamics problem. I.e. the pure *Neumann* boundary problem will be considered first, before different possibilities of imposing *Dirichlet* boundary conditions in general, will be discussed afterwards. Based on this, the inverse dynamics problem will be introduced in context of spatially discrete mechanical systems subjected to rheonomic holonomic servo-constraints (cf. [1]). A detailed analysis of this type of constrained systems aims to elaborate the fundamental distinctions of servo-constraints to classical contact-constraints. Consequences thereof, regarding the construction of numerically stable integration methods, will be addressed likewise (cf. [2]).

Due to the highly restrictive applicability of solving the inverse dynamics problem sequentially in space and time, an in-depth analysis of the underlying initial boundary value problem is being pursued. Especially by exposing the underlying hyperbolic structure of the governing partial differential equations, further insights into the problem at hand are anticipated. Enlighting the resulting mechanisms of wave propagation within continuous structures will pave the way to a numerically stable integration of the inverse dynamics problem. Thus, e.g. a method that is based on the integration of partial differential equations along characteristic manifolds is presented. This motivates the development of novel Galerkin methods that can be presented in this work as well (cf. [3, 4]).

These newly established methods can be applied to the feed-forward control problem of various mechanical systems. In addition to that, the novel simultaneous space-time integration methods are adopted to flexible multibody systems such as e.g. the cooperative control of a rigid body through several flexible strings or the tendon-driven control of the end-effector of highly flexible robot arms.

Selected numerical examples are given, underlining the relevance of the proposed simultaneous space-time integration.

[1] W. Blajer, K. Kołodziejczyk. *Control of Underactuated Mechanical Systems with Servo-Constraints*, Nonlinear Dynamics, 50 (2007) 781-791.

[2] R.Altmann, P.Betsch, Y.Yang. *Index Reduction by Minimal Extension for the Inverse Dynamics Simulation of Cranes*, Multibody System Dynamics, 36 (2016) 295-321.

[3] T. Ströhle, P. Betsch. *A Simultaneous Space-Time Discretization Approach to the Inverse Dynamics of Geometrically Exact Strings*, Int. J. Numer. Meth. Engng, 123 (2022) 2573-2609.

[4] T. Ströhle, P. Betsch. *Inverse Dynamics of Geometrically Exact Beams*, Proceedings of the ECCOMAS Congress 2022, 8th European Congress on Computational Methods in Applied Sciences & Engineering, Oslo, Norway, 5-9 June 2022.

Prof. Dr.-Ing. P. Steinmann
Prof. Dr.-Ing. K. Willner
Technische Mechanik
Egerlandstraße 5, 91058 Erlangen

Prof. Dr.-Ing. S. Leyendecker
Technische Dynamik
Immerwahrstraße 1, 91058 Erlangen

Prof. Dr.-Ing. S. Budday
Kontinuumsmechanik und Biomechanik
Egerlandstraße 5, 91058 Erlangen