Centro de Investigación en Ingeniería Matemática

Universidad de Concepción

CI^{2}MA Focus Seminar
on the occasion of the visit by Professors Drs. Michael Fister and Andreas Meister
(Universität Kassel, Germany)
Universidad de Concepción, December 6, 2024
Centro de Investigación en Ingeniería Matemática (CI^{2}MA),
Auditorio Hermann Alder Weller
Organizers[1]: Rodolfo Araya and Raimund Bürger

14.00–14.40 **Michael Fister** (Universität Kassel, Institute for Driveline and Vehicle Technology, Chair of Mechatronics with the Focus on Vehicles):

Digital Twin for a Truck Driveline Test Bench for Convential and Electric Axles

Summary. For acceleration of the research and development process it is very helpful to simulate the behavior of technical devices prior to implementation as a model on a computer, which is called a Digital Twin. Possible advantages of this concept are:

- Avoid damages to the real equipment through undetected failures in the complex automatization.
- Receiving interface information of physical status of areas, where no physical sensors are placed.
- Proceed of simulated test runs, to check if all signals have the right connection
- and so on.

This presentation explains the physical realty of a professional driveline test bench which was completely developed and build at the University of Kassel. It shows the set up, how the Digital Twin is implemented, examples of the modelling of real components and examples of the outcomes. The presentation will end with an outlook to the actual research area, using Artifical Intelligence (AI) as a failure prediction tool.

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14.40–15.20 **Andreas Meister** (Universität Kassel, Department of Mathematics and Natural Sciences):

Modified Patankar-Runge-Kutta Methods: Introduction, Analysis and Numerical Applications

Summary. Mathematical modeling leads to so-called convection-diffusion-reaction equations in the form of systems of partial differential equations in numerous practical applications. Examples are turbulent air flows or algae growth in oceans or lakes. After discretization of the spatial derivatives, an extremely large system of ordinary differential equations occurs. A reasonable numerical time integration scheme must reflect present properties like the positivity of single balance quantities or also the conservativity of the initial model. In the talk we will present so-called modified Patankar-Runge-Kutta (MPRK) schemes. They adapt explicit Runge-Kutta schemes in a way to ensure positivity and conservativity irrespective of the time step size. Thereby, we introduce a general definition of MPRK schemes and present a thorough investigation of necessary as well as sufficient conditions to derive first, second and third order accurate MPRK schemes. The theoretical results will be confirmed by numerical experiments in which MPRK schemes are applied to solve non-stiff and stiff systems of ordinary differential equations. Furthermore, we investigate the efficiency of MPRK schemes in the context of convection-diffusion-reaction equations with source terms of production-destruction type.

15.20–16.00 **Manuel Solano** (CI^{2}MA and Departamento de Ingeniería Matemática, Universidad de Concepción):

A mixed finite element method for coupled fluid flow problems arising from reverse osmosis modeling

Summary. We consider a mathematical model for addressing coupled fluid flow problems arising from reverse osmosis modeling in water desalination processes. It consists of the coupled Navier Stokes/transport equations, with nonlinear conditions across a semipermeable membrane. To solve these set of partial differential equations, we employ a new mixed finite element method able to capture several variables of interest such as the salt concentration level, pressure drop and fluid velocity. Through diverse numerical simulations and a variety of configurations, we illustrate the capability of the method to accurately capture the behaviour of saline water when passing through membrane-based reverse osmosis desalination channels.

16.00–16.30 **Coffee break**

16.30–17.10 **Jorge Aguayo** (Centro de Modelamiento Matemático, Universidad de Chile):

Mixed finite element schemes for the elasticity equation and its application in subduction earthquake modeling

Summary. One of the most impactful natural disasters is earthquakes, which have devastated various locations in Chile, Japan, Indonesia, among other countries on the Pacific coast. Subduction earthquakes can be modeled from an elasticity equation governed by a tangential jump condition on a tectonic fault, also called coseismic slip, together with transmission conditions in the direction normal to the fault. The use of seismic sensors allows measuring vibrations, displacements, and tractions on the surface of the earth's bed, but it has not been possible to fully estimate the deformation field using techniques that ensure precision, stability and speed in computations. The talk will present a numerical scheme based on mixed finite elements to solve the linear elasticity equation with coseismic slip and an optimal control problem that seeks to estimate the coseismic slip and the respective states. These results will be complemented with realistic synthetic tests of a subduction earthquake on a tectonic fault located at the Pacific coast.

17.10–17.50 **Raimund Bürger** (CI^{2}MA and Departamento de Ingeniería Matemática, Universidad de Concepción):

A multilayer shallow water model for tsunamis and coastal forest interaction

Summary. Models and numerical methods of the impact of tsunamis on coastal forests are of vital importance for exploring the potential of coastal vegetation as a means of mitigation. Such a model is formulated as a multilayer shallow water system based on a free-surface formulation of the Euler equations for an ideal fluid. Specifically, the Euler equations are approximated by a layer averaged non-hydrostatic (LDNH) approach involving linear pressures, piecewise constant horizontal velocities and piecewise linear vertical velocities. Furthermore, based on Iimura and Tanaka [Iimura, K.; Tanaka, N., *Numerical simulation estimating effects of tree density distribution in coastal forest on tsunami mitigation,* Ocean Engrg. **54** (2012), 223–232], drag forces, inertia forces, and porosity are added to model the interaction with the forest. These ingredients are specified in a layer-wise manner. Thus, the vertical features of the forest are described with higher accuracy than within a single-layer approach. Projection methods for the non-hydrostatic pressure in conjunction with polynomial viscosity matrix finite volume methods [Castro, M. J.; Fernández-Nieto, E., *A class of computationally fast first order finite volume solvers: PVM methods,* SIAM J. Sci. Comput. **34**, (2012) A2173–A2196] are employed for the numerical solution of the multilayer model, that is for the propagation of tsunamis and coastal flooding. Experimental observations and field data are used to validate the model. In general good agreement is obtained. Results indicate, moreover, that coastal vegetation can operate as an efficient natural barrier against coastal hazards and can significantly reduce the effects of tsunamis.

20.00 **Seminar dinner** TBA.