Advances in modeling and numerical methods for fluid flow problems

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Abstract

The development of mathematical models and numerical methods for the simulation of fluid flows relates to numerous, diverse applications. Some examples include weather predication, aerodynamics, and modeling ocean currents. However, direct numerical simulation of many flows will fail due to prohibitive computational resources. Thus, necessitating the development of models for fluid flows as well as accurate and efficient numerical techniques. This minisymposium will focus on recent advances in mathematical models and numerical methods for quasigeostrophic flows, turbulent incompressible fluid flows, and non-Newtonian fluid flows.

Session 1:

- **Speaker:** *Paul Kuberry* (pkuberry@gmail.com), Clemson University,

  Title: A decoupling algorithm for fluid-structure interaction problems based on optimization

  Abstract: Fluid-structure interactions are challenging to simulate because of the tight coupling between the fluid and solid substructures. Explicit and implicit decoupling methods often either fail or require relaxation when densities of the two materials are close. In this talk, a Neumann control enforcing the continuity of stress on the interface is introduced to minimize the jump in velocities of the two substructures. A decoupling optimization algorithm is discussed and numerical results are presented.

- **Speaker:** *Nicholas Wilson* (newilson@mtu.edu), Michigan Technological University,

  Title: High accuracy method for magnetohydrodynamics system in Elsässer variables

  Abstract: A method has been developed recently by C. Trenchea, that allows for decoupling of the evolutionary full MagnetoHydroDynamics (MHD) system in the Elsässer variables. The method entails the implicit discretization of the subproblem terms and the explicit discretization of coupling terms, and was proven to be unconditionally stable. In this presentation we build on that result by introducing a high-order accurate deferred correction method, which also decouples the MHD system. We perform the full numerical analysis of the method, proving the unconditional stability and second order accuracy of the two-step method. We also use a test problem to verify numerically the claimed convergence rate.

- **Speaker:** *Abigail Bowers* (abowers@clemson.edu), Clemson University,

  Title: Numerical study of a regularization model for incompressible flow with deconvolution-based adaptive nonlinear filtering

  Abstract: We study a trapezoidal-in-time, finite-element-in-space discretization of a new Leray regularization model that locally chooses the filtering radius using a deconvolution based indicator function to identify regions where regularization is needed. Because this indicator function is mathematically based, it allows us to establish a rigorous analysis of the resulting numerical algorithm. We prove well-posedness, unconditional stability, and convergence of the proposed algorithm, and test the model on several benchmark problems.

- **Speaker:** *Kuo Liu* (kliu@fsu.edu), Florida State University,

  Title: Hybrid First-Oder System Least-Squares Finite Element Method with Application to Stokes and Navier-Stokes equation

  Abstract: Standard First-Oder System Least-Squares finite element method has been critized for its poor performance on mass conservation. In this talk, we show this is essentially due to its lack of control on error's L^2 norm. We propose a novel hybrid formulation , demonstrate its execellent control on both error's L^2 norm and H^1 norm, both analytically and numerically. We develop the hybrid formulation for both Stokes and Navier-Stokes equations, using regular domain and domain with an re-entrant corner.

Session 2:

- **Speaker:** *Shuhan Xu* (shuhanx@g.clemson.edu), Clemson University,

  Title: Numerical study for viscoelastic fluid-structure interaction

  Abstract: We consider a fluid-structure problem where the fluid is viscoelastic and the structure is represented by the one-dimensional string model. The coupled problem is decomposed into a fluid subproblem and a structure subproblem. In the fluid problem the Arbitrary Lagrangian Eulerian (ALE) formulation is used to develop a numerical algorithm in the setting of finite element method, while the geometric conservation law (GCL) is considered in time discretization. We will discuss a numerical algorithm for a time stepping scheme to carry out a fluid-structure simulation.

- **Speaker:** *Hoang Tran* (hat25@pitt.edu), University of Pittsburgh,

  Title: Partitioned Time-stepping Methods for Uncoupling Evolutionary Groundwater-Surface Water Flows

  Abstract: Many important applications require the accurate solution of coupling of groundwater flows with surface flows (the Stokes-Darcy problem). The essential problems of estimation of the penetration of a plume of pollution into groundwater and remediation after such a penetration are that (i) the large domains plus the need to compute for several turn-over times for reliable statistics require calculations over long time intervals and (ii) values of some system parameters, e.g., hydraulic conductivity and specific storage, are frequently very small. We propose partitioned methods for fully time dependent Stokes-Darcy problems and analyze their stability and errors over long time intervals. Uncoupling a coupled problem necessarily induces a timestep restriction for long time stability. We study and test the severity of such restrictions in case of small system parameters. This is joint work with William Layton, Catalin Trenchea and Xin Xiong.

- **Speaker:** *Alexander Labovsky* (aelabovs@mtu.edu), Michigan Technological University,

  Title: Can a Defect Correction Method Be Viewed As a Turbulence Model?

  Abstract: A method for resolving turbulent flows is sought, which is faster than the existing approaches, and competitive in terms of stability and accuracy. We introduce a Defect Correction Method (DCM) for approximating the averaged solution of (turbulent) Navier-Stokes equations, and we compare it against the Approximate Deconvolution Model of turbulence. We prove stability of the method, verify its accuracy numerically, and demonstrate the superiority of DCM in terms of CPU time.

- **Speaker:** *Keith Galvin* (kjgalvi@clemson.edu), Clemson University,

  Title: TBA

  Abstract: To be announced.