Super-Convergent IMEX-Peer Methods with Variable Time Steps

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R 3.07 Mon Z1 14:00-14:25

Dynamical systems with sub-processes evolving on many different time scales are ubiquitous in applications. Their efficient solution is greatly enhanced by automatic time step variation. In this talk, I will present the theory, construction and application of IMEX-Peer methods that are super-convergent for variable step sizes and A-stable in the implicit part [5]. IMEX-Peer schemes – like other IMEX-methods as well – combine the necessary stability of implicit and low computational costs of explicit methods to efficiently solve systems of ordinary differential equations with both stiff and non-stiff parts included in the source term [1,2,3,4]. To construct super-convergent IMEX-Peer methods which keep their higher order for variable step sizes and exhibit favourable linear stability properties, we derive necessary and sufficient conditions on the nodes and coefficient matrices and apply an extrapolation approach based on already computed stage values. New super-convergent IMEX-Peer methods of order $s+1$ for $s = 2, 3, 4$ stages are given as result of additional order conditions which maintain the super-convergence property independent of step size changes. Numerical experiments and a comparison to other super-convergent IMEX-Peer methods show the potential of the new methods when applied with local error control.

[1] Lang and Hundsdorfer: Extrapolation-based implicit-explicit Peer methods with optimised stability regions, J. Comp. Phys. 337 (2017), 203-215.

[2] Soleimani, Knoth and Weiner: IMEX Peer methods for fast-wave-slow-wave problems, Appl. Numer. Math. 118 (2017), 221-237.

[3] Soleimani and Weiner: Superconvergent IMEX Peer methods, Appl. Numer. Math. 130 (2018), 70-85.

[4] Schneider, Lang and Hundsdorfer: Extrapolation-based superconvergent implicit-explicit Peer methods with A-stable implicit part, J. Comp. Phys. 367 (2018), 121-133.

[5] Schneider, Lang and Weiner: Super-convergent implicit-explicit Peer methods with variable step sizes, J. Comput. Appl. Math. 387 (2021), 112501