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Efficient numerical solution of spatially variable coefficients ADR equations using exponential integrators

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Due to the importance of simulation in various fields of science and engineering, devising efficient numerical methods for solving high-dimensional evolutionary Partial Differential Equations is of considerable interest. In this talk, we present an efficient technique to employ exponential integrators for solving evolutionary Advection-Diffusion-Reaction equations with *spatially variable* coefficients, i.e., in form

$$\begin{bmatrix} \partial_t u(t,x) = \nabla \cdot (\lambda(x) \nabla u(t,x)) + r(t,x,u(t,x)), \quad t \in [0,T], \quad x \in \Omega \subset \mathbb{R}^d \\ u(0,x) = u_0(x) \end{bmatrix}$$

coupled with appropriate boundary conditions. The approach is based on the extraction from the original PDE of a constant coefficient diffusion part, which is determined by a linear stability analysis of the chosen temporal scheme. After semidiscretization in space, the arising stiff system of Ordinary Differential Equations can then be numerically integrated efficiently by employing, for instance, Fast Fourier Transform or Kronecker/tensor μ-mode based techniques.

In this context, we also consider two new exponential integrators of Lawson type (of first and second order), which appear to have better unconditional stability bounds compared to other well-established exponential integrators.

The validity and effectiveness of the approach is highlighted by presenting numerical experiments in one space dimension and by showing performance results on Advection-Diffusion-Reaction equations in two and three space dimensions, which exhibit a neat advantage compared to state-of-the-art techniques.

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