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Robust Solution of Singularly Perturbed Systems of Reaction-Diffusion Equations

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Coupled systems of singularly perturbed reaction-diffusion equations arise in many applications areas, from chemical engineering to modelling of turbulent flows. The numerical solution of these equations is complicated by the need to properly resolve boundary layers, even in the simplest, linear cases. While there have been significant advances in the development of robust discretizations, much less attention has been given to the problem of solving the associated linear systems.

In this talk, we present the development of geometric and algebraic multigrid approaches for these problems that are robust with respect to the perturbation parameter(s). Starting from uniformly convergent finite-difference discretizations on meshes chosen to adequately and efficiently resolve both the boundary layers and interior region, we demonstrate robust multigrid performance with respect to both mesh resolution and the singular perturbation parameters. While algebraic multigrid approaches offer excellent scaling performance, we show that geometric approaches can achieve similar scaling with much lower computational overhead.