Strong Stability Preserving Integrating Factor Runge--Kutta Methods

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Strong stability preserving (SSP) Runge--Kutta methods are often desired when evolving in time problems that have two components that have very different time scales. For problems with a linear component that is stiff and a nonlinear component that is not, integrating factor methods offer an attractive alternative to traditional time-stepping methods.

In this talk we show that it is possible to define explicit integrating factor Runge--Kutta methods that preserve the desired strong stability properties satisfied by each of the two components when coupled with forward Euler time-stepping, or even given weaker conditions. We define sufficient conditions for an explicit integrating factor Runge--Kutta method to be SSP, namely that they are based on explicit SSP Runge--Kutta methods with non-decreasing abscissas. We find such methods of up to fourth order and up to ten stages, analyze their SSP coefficients, and prove their optimality in a few cases. We test these methods to demonstrate their convergence and to show that the SSP time-step predicted by the theory is generally sharp, and that the non-decreasing abscissa condition is needed in our test cases. Finally, we show that on a typical total variation diminishing nonlinear test-case our new explicit SSP integrating factor Runge--Kutta methods out-perform the corresponding explicit SSP Runge--Kutta methods, implicit-explicit SSP Runge--Kutta methods, and some well-known exponential time differencing methods.

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