Explicit Singly Diagonally Implicit Runge-Kutta Methods and Adaptive Stepsize Control for Reservoir Simulation

The implicit Euler method, normally referred to as the fully implicit (FIM) method, and the implicit pressure explicit saturation (IMPES) method are the traditional choices for temporal discretization in reservoir simulation. The FIM method offers unconditionally stability in the sense of discrete approximations, while the IMPES scheme benefits from the explicit treatment of the saturation. However, in terms of controlling the integration error, the low order of the FIM method leads to small integration steps, while the explicit treatment of the saturation may restrict the stepsizes for the IMPES scheme. Current reservoir simulators apply timestepping algorithms that are based on safeguarded heuristics, and can neither guarantee convergence in the underlying equation solver, nor provide estimates of the relations between convergence, integration error and stepsizes. We establish predictive stepsize control applied to high order methods for temporal discretization in reservoir simulation. The family of Runge-Kutta methods is presented and in particular the explicit singly diagonally implicit Runge-Kutta (ESDIRK) method with an embedded error estimate is described. A predictive stepsize adjustment rule based on error estimates and convergence control of the integrated iterative solver is presented. We try to improve the predictive stepsize control through an extended communication between the convergence rate, the error control and the stepsizes. Keywords: Reservoir simulation, implicit Runge-Kutta methods, ESDIRK, Newton-Raphson, convergence control, error control, stepsize selection.

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