Explicit Energy-Preserving Momentum-Scaling Schemes for Hamiltonian Systems

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We introduce a novel class of explicit energy-preserving momentum-scaling (EPMS) schemes for Hamiltonian systems of the form $H(\boldsymbol{q}, \boldsymbol{p}) = \frac{1}{2}\boldsymbol{p}^T M^{-1}(\boldsymbol{q})\boldsymbol{p} + U(\boldsymbol{q})$. EPMS schemes consist of two main steps: first, utilize an explicit scheme satisfying a non-degenerate condition; second, follow by scaling of momentum variables to achieve exact energy preservation. We show that EPMS schemes are consistent. Moreover, we give a sufficient condition for explicit Runge-Kutta methods to satisfy the non-degenerate condition, showing that a wide class of explicit Runge-Kutta methods can be turned into EPMS schemes. Numerical experiments showcasing computational efficiency of EPMS schemes versus implicit energy-preserving schemes are presented.

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