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Randomised one-step time integration methods for deterministic operator differential equations

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Uncertainty quantification plays an important role in applications that involve simulating cascades of trajectories of dynamical systems. Conrad et al. (2007, 2009), 2017) proposed randomisation of deterministic time integration methods as a strategy for quantifying uncertainty due to time discretisation. We consider this strategy for systems that are described by deterministic, possibly nonautonomous operator differential equations defined on a Banach space or a Gel'fand triple. We prove pathwise and expected error bounds on the random trajectories, given an assumption on the local truncation error of the underlying deterministic time integration and an assumption that the absolute moments of the random variables decay with the time step. Our analysis shows that the error analysis for differential equations in finite-dimensional Euclidean space carries over to infinite-dimensional settings.

1. Introduction

The numerical solution of deterministic dynamical systems is an important task in many applications where the dynamical system is a spatiotemporal field that satisfies a partial differential equation (PDE). In this case, the field can be viewed as a function u mapping to an infinite-dimensional real separable Banach space $(V, \|\cdot\|)$, and the dynamical system is described by a deterministic operator differential equation

$$u'(t) = f(t, u(t)), \quad (1.1)$$

where u' denotes the time derivative of the function u over a given bounded deterministic time interval. Operator differential equations have been applied in celestial dynamics [3], as well as peridynamics and elastic materials [13, 20].

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