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A higher order weak approximation scheme of multidimensional stochastic differential equations using Malliavin weights

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Abstract

We show a new higher order weak approximation with Malliavin weights for multidimensional stochastic differential equations by extending the method in Takahashi and Yamada (2016). The estimate of global error of the discretization is based on a sharp small time expansion using a Malliavin calculus approach. We give explicit Malliavin weights for second order discretization as polynomials of Brownian motions. The effectiveness is illustrated through an example in option pricing.

Keywords: Weak approximation, Stochastic differential equations, Malliavin calculus

1. Introduction

Developing a weak approximation method for stochastic differential equations (SDEs) is an important topic in stochastic analysis and their related fields since many interesting quantities are given by expectations of SDEs. The most popular weak approximation method is the Euler-Maruyama scheme, introduced by G. Maruyama [17] as Euler's numerical approximation for SDEs. The Euler-Maruyama scheme is widely used as basic method due to the ease of its implementation and is known as the first order weak approximation (cf. [1]) in theoretical aspect. So far, there has been a large number of studies on weak approximation of SDEs in order to obtain more effective or accurate scheme (see the book [9] and [3] for example).

In [20], the authors developed an efficient weak approximation using asymptotic expansion with Malliavin calculus [21]. The method gives a useful approximation since we can expect the effects of accuracy of both effects of small noise asymptotic expansion and discretization.

In this paper, we focus on deriving a higher order weak approximation of SDEs by extending the method in [20]. In particular, a sharp small time expansion (or local approximation) is shown as an extension of [20] in order to obtain a higher order discretization while [20] intended to show an improvement

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