

FORMULAE FOR MIXED MOMENTS OF WIENER PROCESSES AND A STOCHASTIC AREA INTEGRAL *

YOSHIO KOMORI[†], GUOQUO YANG[‡], AND KEVIN BURRAGE[§]

Abstract. This paper deals with the expectation of monomials with respect to the stochastic area integral

$$A_{1,2}(t, t+h) = \int_t^{t+h} \int_t^s dW_1(r) dW_2(s) - \int_t^{t+h} \int_t^s dW_2(r) dW_1(s)$$

and the increments of two Wiener processes, $\Delta W_i(t, t+h) = W_i(t+h) - W_i(t)$, $i = 1, 2$. In a monomial, if the exponent of one of the Wiener increments or the stochastic area integral is an odd number, then the expectation of the monomial is zero. However, if the exponent of any of them is an even number, then the expectation is nonzero and its exact value is not known in general. In the present paper, we derive formulae to give the value in general. As an application of the formulae, we will utilize the formulae for a careful stability analysis on a Magnus-type Milstein method. As another application, we will give some mixed moments of the increments of Wiener processes and stochastic double integrals.

Key words. High order moment, stochastic integral, stochastic differential equation, stability analysis, numerical method

MSC codes. 60H10, 60H30, 65C30

1. Introduction. We are concerned with developing and analyzing numerical methods that give strong first order approximations to the solution of noncommutative stochastic differential equations (SDEs). Such methods are usually constructed on the basis of the comparison with the Itô–Taylor expansion or the Stratonovich–Taylor expansion, and as a result, they have one or more terms related to the stochastic area integral

$$A_{i,j}(t, t+h) = \int_t^{t+h} \int_t^s dW_i(r) dW_j(s) - \int_t^{t+h} \int_t^s dW_j(r) dW_i(s),$$

where $t \geq 0$, $h > 0$, and where $W_i(t), W_j(t)$ are independent Wiener processes for positive integers i, j ($i \neq j$).

Lévy [13] has studied the stochastic area integral by utilizing the Fourier series of Wiener process. As an example, he has given the probability density function of $A_{1,2}(0, 1)$. Gaveau [6] has also studied the stochastic area integral and shown a joint density function in general form, which is related to Wiener increments and stochastic area integrals.

The joint density of the stochastic area integral $A_{1,2}(t, t+h)$ and the Wiener increments $\Delta W_i(t, t+h) = W_i(t+h) - W_i(t)$, $i = 1, 2$, can be used to generate random numbers which approximate the stochastic area integral. In fact, by utilizing a conditional joint density function of them, Gaines and Lyons [5] have proposed a

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Stochastic Processes And The Wiener Integral

Dimitŭr Baĭnov



Stochastic Processes And The Wiener Integral:

Stochastic Processes and the Wiener Integral Jui-ching Yeh, 1973 *Chaos Expansions, Multiple Wiener-Ito Integrals, and Their Applications* Christian Houdre, Victor Perez-Abreu, 1994-04-05 The study of chaos expansions and multiple Wiener Ito integrals has become a field of considerable interest in applied and theoretical areas of probability stochastic processes mathematical physics and statistics Divided into four parts this book features a wide selection of surveys and recent developments on these subjects Part 1 introduces the concepts techniques and applications of multiple Wiener Ito and related integrals The second part includes papers on chaos random variables appearing in many limiting theorems Part 3 is devoted to mixing zero one laws and path continuity properties of chaos processes The final part presents several applications to stochastic analysis *Stochastic Processes and the Wiener Integral* Jui-ching Yeh, 1973 **Stochastic Processes and the Wiener Integral** James Jui-tin Yeh, 1992 **Essentials of Stochastic Processes** Kiyosi Itô, 2006 This book is an English translation of Kiyosi Ito s monograph published in Japanese in 1957 It gives a unified and comprehensive account of additive processes or Levy processes stationary processes and Markov processes which constitute the three most important classes of stochastic processes Written by one of the leading experts in the field this volume presents to the reader lucid explanations of the fundamental concepts and basic results in each of these three major areas of the theory of stochastic processes With the requirements limited to an introductory graduate course on analysis especially measure theory and basic probability theory this book is an excellent text for any graduate course on stochastic processes Kiyosi Ito is famous throughout the world for his work on stochastic integrals including the Ito formula but he has made substantial contributions to other areas of probability theory as well such as additive processes stationary processes and Markov processes especially diffusion processes which are topics covered in this book For his contributions and achievements he has received among others the Wolf Prize the Japan Academy Prize and the Kyoto Prize **Stochastic Calculus for Fractional Brownian Motion and Related Processes** Yuliya Mishura, 2008-04-12 This volume examines the theory of fractional Brownian motion and other long memory processes Interesting topics for PhD students and specialists in probability theory stochastic analysis and financial mathematics demonstrate the modern level of this field It proves that the market with stock guided by the mixed model is arbitrage free without any restriction on the dependence of the components and deduces different forms of the Black Scholes equation for fractional market **Non-Gaussian Selfsimilar Stochastic Processes** Ciprian Tudor, 2023-07-04 This book offers an introduction to the field of stochastic analysis of Hermite processes These selfsimilar stochastic processes with stationary increments live in a Wiener chaos and include the fractional Brownian motion the only Gaussian process in this class Using the Wiener chaos theory and multiple stochastic integrals the book covers the main properties of Hermite processes and their multiparameter counterparts the Hermite sheets It delves into the probability distribution of these stochastic processes and their sample paths while also presenting the basics of stochastic integration

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Introduction to Stochastic Integration Hui-Hsiung Kuo, 2006-02-04 In the Leibniz Newton calculus one learns the differentiation and integration of deterministic functions A basic theorem in differentiation is the chain rule which gives the derivative of a composite of two differentiable functions The chain rule when written in an indefinite integral form yields the method of substitution In advanced calculus the Riemann Stieltjes integral is defined through the same procedure of partition evaluation summation limit as in the Riemann integral In dealing with random functions such as functions of a Brownian motion the chain rule for the Leibniz Newton calculus breaks down A Brownian motion moves so rapidly and irregularly that almost all of its sample paths are nowhere differentiable Thus we cannot differentiate functions of a Brownian motion in the same way as in the Leibniz Newton calculus In 1944 Kiyosi Itô published the celebrated paper Stochastic Integral in the Proceedings of the Imperial Academy Tokyo It was the beginning of the Itô calculus the counterpart of the Leibniz Newton calculus for random functions In this six page paper Itô introduced the stochastic integral and a formula known since then as Itô's formula The Itô formula is the chain rule for the Itô calculus But it cannot be expressed as in the Leibniz Newton calculus in terms of derivatives since a Brownian motion path is nowhere differentiable The Itô formula can be interpreted only in the integral form Moreover there is an additional term in the formula called the Itô correction term resulting from the nonzero quadratic variation of a Brownian motion

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