

Catherine Donati-Martin
Michel Émery
Alain Rouault
Christophe Stricker (Eds.)

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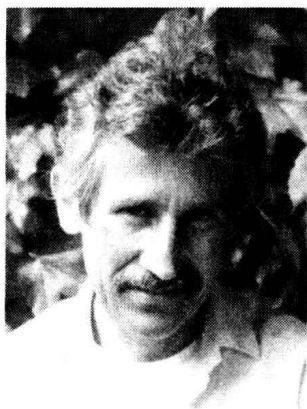


Photo by George Bergman.

Marc Yor, one of the most prominent members of the French probabilistic school, is turning 60. For the last 33 years, he contributed to the Séminaire by his own articles and his counselling of other authors; his methods and style permeate throughout the volumes of this series. He was a tireless member of the Rédaction during a quarter of a century, from Volume XIV to XXXIX, careful to maintain the highest quality, from broad mathematical ideas to minutest details. We wish we were able to keep up with the high standards he has set! Since Volume XL, he is no longer an official rédacteur, but keeps helping us with the editorial work and the refereeing.

Marc, nous te souhaitons un joyeux anniversaire, et nous sommes heureux de te dédier ce volume.

Catherine Donati-Martin, Michel Émery,
Alain Rouault, Christophe Stricker

Preface

Nine volumes ago, in Séminaire de Probabilités XXXIII, a series of advanced courses was started; nine such courses have appeared since. Two of them are due to Antoine Lejay, including his *Introduction to rough paths* in volume XXXVII. This unrepentant recidivist now strikes again, with *Yet another introduction to rough paths*, which sheds a more algebraic light on the same matter.

The various contributions which constitute the rest of the volume exemplify the rôle the Séminaire intends to play on the probabilistic stage: junior authors go side by side with older contributors, with a predominance from French or francophile ones; short notes mix with real research articles; and the themes are well in the traditional spirit of the Séminaire, ranging over the broad spectrum of interest of the readership of the Séminaire.

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Yet Another Introduction to Rough Paths

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Summary. This specialized course provides another point of view on the theory of rough paths, starting with simple considerations on ordinary integrals, and stressing the importance of the Green-Riemann formula, as in the work of D. Feyel and A. de La Pradelle. This point of view allows us to gently introduce the required algebraic structures and provides alternative ways to understand why the construction of T. Lyons *et al.* is a natural generalization of the notion of integral of differential forms, in the sense that it shares the same properties as integrals along smooth paths, when we use the “right notion” of a path.

Key words: Rough paths; integral of differential forms along irregular paths; controlled differential equations; Lie algebra; Lie group; Chen series; sub-Riemannian geometry

1 Introduction

The theory of rough paths [42, 44, 52, 55] is now an active field of research, especially among the probabilistic community. Although this theory is motivated by stochastic analysis, it takes its roots in analysis and control theory, and is also connected to differential geometry and algebra.

Given a path x of finite p -variation with $p \geq 2$ on $[0, T]$ with values in $\mathbb{R}^d$ or an α -Hölder continuous path with $\alpha \leq 1/2$, this theory allows us to define the integral $\int_x f$ of a differential form f along x , which is $\int_x f = \int_0^T f(x_s) dx_s$. Using a fixed point theorem, it is then possible to solve differential equations driven by x of type

$$y_t = y_0 + \int_0^t g(y_s) dx_s.$$

The case $1 \leq p < 2$ (or $\alpha > 1/2$) is covered by the Young integrals introduced by L.C. Young in [73]. Some of the most common stochastic processes, including Brownian motion, have trajectories that are of finite p -variation with