Princeton University
Department of Operations Research and Financial Engineering

CONTRIBUTIONS A L'ESTIMATION NON LINEAIRE ET AUX SYSTEMES DE PARTICULES EN INTERACTION

Avec applications au filtrage non lineaire, controle optimal, formulas de Feynman-Kac et operateurs de Schrödinger.

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Review of the Thesis

The thesis comprises four distinct parts, but by lack of competence and of time, I will ignore the last part devoted to the idempotent probability calculus, and instead, I will concentrate on the first three parts with which I am more familiar.

Part I deals with the analysis of the particle systems introduced as approximations of the optimal filters in nonlinear stochastic systems. Del Moral contribution can be found in a series of four papers with Guionnet, and four other papers with Jacod. They provide a complete analysis of the particle approximations, and they form the foundation of the subject. This body of work is very impressive, and there is no doubt that it is at the origin of the reputation of Pierre Del Moral, and the high opinion people have of his work.

Part II is concerned with the connection of the dynamical evolutions of particles introduced in filtering, with the genetic algorithms of Holland as analyzed by Cerf. Del Moral identifies the ties between these apparently different algorithms, and builds on these connections to prove new convergence results for optimization algorithms.

Part III is devoted to the analysis of the asymptotic contraction property of positivity preserving semi-groups. As before, the original motivation was from filtering theory. This fact shows clearly in the two joint works with Miclo, while the joint work with Ledoux and Miclo is more in line with the abstract framework of Markovian semi-groups. The main interest of these results is the reliance on the finite time properties of

the transitions. This is in contrast with the traditional approaches that rely mostly on the properties of the invariant measure(s). A lot has been written on Schrödinger operator semi-groups, and it is quite likely that some of the results presented in the first part of the second paper with Miclo may be improved, but the analysis of the nonlinear Feynman-Kac semi-groups is original, especially the part dealing with particle approximations. In fact, I believe that this part has a great potential for numerical implementations. The part on the analysis of the contraction properties of Markovian semi-groups offers a fresh (and modern) look at some of the ergodic properties of Markovian systems.

Even though some sections are made difficult to read by the desire to include in the same presentation, both the discrete time and the continuous time cases, the sum of all the articles gathered in this thesis represents an impressive body of work, not only because of the quantity of the results, but also because of the depth of some of the estimates, and the rigor and the quality of the mathematical derivations.

Evaluation as a Researcher

Pierre Del Moral was one of the first probabilists to realize the enormous potential of the particle methods of filtering, both from the theoretical point of view and the practical point of view. His solid French mathematical training together with an early engineering education helped him position himself as a world leader in a field who had been dominated by more traditional stochastic analysts. Indeed, not much progress seemed to occur in the analysis of the various forms of the stochastic partial differential equations giving the nonlinear filters, both from the theoretical and the practical point of view. On the other hand, the spectacular successes of the practical implementations of the particle algorithms stole the attention of the scientific community, and shifted the spotlight to the development of the theory of the particle approximations. These circumstances gave to Pierre's early works on particle filters, instant worldwide exposure. His solid mathematical background and the high quality of his publications made him a leader in the field of filtering, and he is now the most sought after speaker and collaborator in this field. But his contributions are not limited to the filtering applications. Indeed, he pioneered the use of particle system approximations to the computations of nonlinear semi-groups given by Feynman-Kac formulae. This part of his work is not as mature, but it has an enormous potential, especially because many numerical applications have not been investigated yet. He is considered as a very active (if not the most active) contributor to the applications of particle methods in filtering, but he is definitely the world leader in the theoretical developments and applications of particle methods in the analysis of nonlinear Feynman-Kac semi-groups.

Evaluation as a Teacher

Pierre Del Moral visited Princeton University last Fall, and he taught a graduate course on filtering by particle methods. His task was extremely difficult because of the lack of homogeneity of the backgrounds of the students attending the class: some PhD students were very advanced, but some Master students were barely cognizant of the most elementary facts of the calculus of probability. After a few lectures of adjustment to the audience, he took control of the class and did an excellent job at pitching his lectures to the right tune. Teaching at Princeton University is taken very seriously, and I was impressed by Pierre's performance.

Evaluation as a Research Adviser

Last fall, I had a chance to witness how Pierre Del Moral was doing as a research adviser: indeed, I had eight PhD students, and very little time to offer to each single one of them. So some of my students went to see him for advise and I saw him help two of my PhD students: one of them being involved in a research program on stochastic filtering, and a second one working on "Feynman-Kac" like representations of solutions of nonlinear partial differential equations of the Hamilton Jacobi type. I was impressed by his capacity to listen to their problems, by his patience, and by the efficiency of the help he provided them with. Both students benefited greatly from Pierre's visit, and especially A. Papavasiliou who is defending her PhD at the end of the month of April, and who secured an Assistant Professorship at Columbia University. This is a very competitive place, and I am convinced that her success owes much to Pierre's help. He strikes me as having all the qualities necessary to be a very attentive and sought after research advisor. With his work ethic, I am sure that he will lead a very productive research team.

Conclusion

For all the reasons detailed above, it is clear that I have the highest opinion of Pierre Del Moral, and I recommend without any reservation that his thesis proposal be accepted.

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