Syllabus for the Ph.D. Course *Latent-State Dynamic Models: Filtering, Inference and Computation*

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Partial information models have a variety of applications in economics and finance, as such a setting arises quite naturally in several fields, ranging from credit risk, to portfolio optimization, to volatility estimation. Because of their practical relevance, statistical inference represents an important issue for these models and the main tool available to perform this crucial task is the mathematical discipline of stochastic filtering, which combines partial observations of a dynamical system with stochastic models in order to infer about its underlying state.

In this course, we give a detailed overview of both theoretical and computational aspects of stochastic filtering. We begin with revisiting fundamental concepts in stochastic calculus and stochastic processes, forming a basis to discuss a brief history of the subject and, in particular, the filtering equations (both in their Kushner-Stratonovich and Zakai form). With a view to real-world applications, we also discuss the concept of *robustness* in the filtering context. Finally, completing the transition from theoretical to more practical aspects of this discipline, we conclude with a survey of numerical (in particular, particle-based) methods to address the filtering problem and the related parameter estimation one.

Specifically, the course consists of three lectures, each covering the following topics:

- **Lecture 1**: brief history of stochastic filtering, statement of the filtering problem, theoretical solution approaches (innovation resp. change of measure) and corresponding filtering equations;
- **Lecture 2**: filters for a hidden Markov chain with finite state space and related Expectation-Maximization (EM) algorithm, *robust* filters (in the sense of Clark, 1978) and their discretization;
- **Lecture 3**: survey of numerical methods addressing the filtering problem, particle filters and particle-based approaches to parameter estimation.

In every lecture, motivating real-world examples are used to initiate discussion: together, we explore how to choose a tractable, yet realistic enough model for the problem at hand, as well as how to apply, extend or adapt state-of-the-art techniques to perform filtering statistical inference in the chosen context. If desired, a comprehensive final assignment will be provided to give students the opportunity to independently challenge themselves with a filtering problem.

Prerequisites for the course include basic knowledge of probability theory and stochastic calculus, and ideally some experience with programming languages (such as R, Python, Matlab or Julia).

References

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- Chopin, N. and Papaspiliopoulos, O., 2020. *An introduction to sequential Monte Carlo* (Vol. 4). Cham, Switzerland: Springer.
- Clark, J.M., 1978. The design of robust approximations to the stochastic differential equations of nonlinear filtering. *Communication systems and random process theory*, *25*.
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- Damian, C., Eksi, Z. and Frey, R., 2018. EM algorithm for Markov chains observed via Gaussian noise and point process information: Theory and case studies. *Statistics & Risk Modeling*, *35*(1-2).
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