Project IV 2024/25

Modern Bayesian computation for stochastic dynamical systems

Models defined by stochastic differential equations (SDEs) allow for the representation of random variability in dynamical systems. SDEs can be used to model many continuous-time processes such as stock price, predator-prey dynamics and epidemics and cellular processes. Solutions of nonlinear SDEs are rarely available in closed form. Consequently, performing simulation and inference for multidimensional SDE models is very challenging. One way to tackle this problem is to use a numerical solver (e.g. Euler-Maruyama, Milstein etc) to generate approximate solutions. Modern Bayesian techniques that leverage the ability to generate approximate discrete-time solutions of SDEs include pseudo-marginal Metropolis-Hastings and approximate Bayesian computation.

This project will focus on these modern simulation-based techniques for fitting discretised SDEs to data. At least one of these methods will be implemented in R and applied to real or synthetic data. Potential application areas will depend on the interests of the project student but could involve stochastic volatility models of financial time series data, stochastic SIR models of epidemic data, predator-prey (Lotka-Volterra) models for data arising from population ecology or models of intra-cellular processes.

Essential prior modules: Bayesian Computation and Modelling III

Resources (indicative)

- Overview of Bayesian inference for SDEs
- ABC for SDEs
- Pseudo-marginal MH for SDEs

Anticipated Outcomes

- A literature review, outlining the role of SDEs as models for continuous-time processes.
- A discussion of existing approaches to Bayesian inference for SDEs with focus on either approximate Bayesian computation or pseudo-marginal Metropolis-Hastings, illustrated with simple examples.
- Application of either inference technique to real and/or synthetic data.
- A suite of bespoke R functions for simulating and fitting nonlinear, multivariate SDEs to discrete-time data.

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