Project IV 2023/24

Bayesian inference for stochastic differential equation models

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 cellular processes. Solutions of nonlinear SDEs are rarely available in closed form. Consequently, performing inference for multidimensional SDE models is very challenging. One way to tackle this problem is to discretise the SDE, for example using a simple Euler-Maruyama discretisation, to give a tractable solution at a set of discrete times. The numerical solution is made arbitrarily accurate by introducing intermediate time points between observation instants and uncertainty between observations is integrated over as part of the inference scheme.

This project will focus on various methods for fitting discretised SDEs to data, including the use of Markov chain Monte Carlo, approximate Bayesian computation (ABC), pseudo-marginal methods and direct approximation of the SDE. Extension of these methods to incomplete data that may be subject to error will also be possible. One or more 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 financial time series data, epidemic data or data arising from population ecology.

Prerequisites: Bayesian Computation and Modelling III. Familiarity with the statistical language R is essential.

Resources (indicative)

- ABC for SDEs
- Overview of Bayesian inference 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 discretised SDEs.
- Focus on one or more inference techniques with application to real or synthetic data.
- Extension of the inference scheme to partial observations.
- A suite of bespoke R functions for simulating and fitting nonlinear, multivariate SDEs to discrete-time data.

Supervisor

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