Aims

The aims of this course are to develop techniques of computational and differential equation modelling in biology, ecology and medicine. This will be done by a mixture of lectures on basic methodology, discussions of research papers, case studies, and group-based modelling exercises. We will introduce a number of modelling approaches that are widely used in applications to the life sciences, including reaction-diffusion equations, age-structured models, multi-scale modelling, and integral representations of dispersal. These methodologies will form the basis for a series of group-based modelling case studies.

Syllabus

Reaction-diffusion models: formulation of reaction-diffusion models and extensions to include advection and chemotaxis terms; applications to pattern and wave phenomena in the life sciences, semi-arid vegetation and wound healing as prototype examples, numerical solution via finite differences in one space dimension (Crank-Nicolson method), implementation of boundary conditions, periodic travelling waves in oscillatory reaction-diffusion equations. (10 lectures)

Integral models for dispersal in ecology: basic approach, kernel selection, thin- and fat-tailed kernels, implementation in integrodifferential and integrodifference models, invasions as a prototype application. (5 lectures)

Multiscale modelling in cell biology: cellular Potts model with tumour angiogenesis as a prototype application. (4 lectures)

Age- and stage-structured models in ecology: discrete time models with age and stage classes, Leslie matrices, estimating the transition matrix from empirical data, fisheries and insect populations as prototype examples. Continuous time age- and stage-structured models (McKendrick–von Foerster equation), measles epidemiology as a prototype example. (4 lectures)

Modelling case studies: group-based work on a mini-project chosen from a list of topics that covers a range of modelling approaches and also a range of applications in the life sciences, including a group-based presentation and an individual written report. (10 lectures)

Throughout the course there will be discussions of relevant research papers, and reviews of these papers will form part of the assessed coursework.
Teaching and Assessment

Contact Hours: 3 lectures and 1 tutorial per week
Assessment: 50% by class tests or other continuous assessment
50% by end of course 2-hour exam
Resit Type: exam for MSc
By the end of the course, students should be able to:

- Formulate scalar and multi-species reaction-diffusion models for a range of processes in biology, ecology and medicine.
- Solve reaction-diffusion equations numerically in one dimension using finite difference methods, for a range of boundary conditions.
- Formulate discrete and continuous time models using integral representations of dispersal.
- Understand the processes via which dispersal kernels can be estimated from empirical data.
- Understand the differences between thin- and fat-tailed kernels and their implications for invasions.
- Understand the cellular Potts model, both in simple single-population models and in more complex multi-population models, with tumour angiogenesis used as a prototype application.
- Formulate discrete time models with age- and stage-structure.
- Formulate continuous time age- and stage-structured models and understand the concept of a long-term age or stage profile.
- Understand the importance of population structure for the dynamics of fish and insect populations, and for the spread of childhood diseases such as measles.
- Understand how to apply a range of modelling and simulation methodologies in real research problems.
- Critically interpret the modelling and simulation components of research papers in mathematical biology ecology and medicine.
- Apply the modelling and simulation methodologies that have been learned in the context of a specific case study.

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