Mathematical models in medicine and mathematical physics

2023/2024 a.y. first semester

Teachers: Vladimir Georgiev (27h) and Maria Laura Manca (15 h)

Introduction

The application of mathematics to biology medicine is an exciting and novel area of research within the discipline of Applied Mathematics. In fact, the complexities of the biological sciences make interdisciplinary involvement essential, and the increasing use of mathematics in biology and medicine is inevitable as these fields becomes more quantitative.

The present course examines some topics in biology and medicine through the lens of mathematics. By the end of this course, students will be able to derive, interpret, solve, understand, discuss, and critique some examples of discrete and differential equation models. Exercises carried out will help him/her to grasp the theoretical concepts.

Highlights

This course covers the fundamentals of some models, in both discrete and continuous time domain, in the sectors of biology and medicine. Techniques and methods covered in lectures will be implemented and demonstrated in computer exercises. Models will originate from various biomedical sectors, including oncology, population dynamics and epidemiology.

Syllabus

Vladimir Georgiev

Introduction to mathematical models in biomedicine. Fibonacci model. Golden section and its association with the Fibonacci sequence. Ordinary differential equations: linear and nonlinear stability. Lotka-Volterra problem and applications, Rosenzweig – Macarthur model. Dulac criterion (periodic solutions do not exist) and applications. Poincare – Bendixson theorem and applications.

Models with partial differential equations: Lotka – Volterra model with diffusion. Models in neuroscience: Kuramoto equation. Schrödinger – Kuramoto model. Idea of synchronization.

Switching from the continuous model to the discrete model. Error and its dependence on the choice of the discretization step.

Compertz model and Bertalanfi model in oncology. Introduction to the SIR model, conservation law. The graph and analysis of the behavior of the solution. Bernoulli model, continuous case.

Maria Laura Manca

What is a mathematical model. Examples. Models of population dynamics. Discrete mathematical model of Malthus. Fibonacci mathematical model. Numerical sequences. Succession of Lucas. First order discrete dynamical systems. Second order discrete dynamical systems (SDD). Examples on the discrete Malthus model. Euler model.

Relationship between second order SDD and golden number. Binet formula. Discrete and continuous mathematical models. Deterministic and stochastic mathematical models. Malthusian fitness. Equilibrium of first order SDDs. Verhulst's mathematical models. Sequence limits in mathematical models of population dynamics.

Introduction to mathematical models in epidemiology. The Bernoulli model. Reed and Frost's mathematical model.
The SI and SIS models. Discrete and continuous form of the epidemic SIR model without and with vaccination. Meaning of R0, Rt and "herd immunity".

Examples and exercises.

Practical information

The course will last 42 hours, and it will take place in the first semester. There will be an oral examination, including questions about the content of the course and a short seminar.

Main prerequisite for this course is curiosity for applications to the world of biology and medicine.

Whoever is interested in knowing more about this course can contact us via e-mail:

vladimir.simeonov.gueorguiev@unipi.it; laura.manca@unipi.it