Data-driven Dynamic Modeling

Course Description

The course is on modeling physical phenomena with ordinary differential equations (ODE). The mathematics of each model is presented. The computational tools for simulation are developed, and models are tested with data.

Course Goals

Upon completion of the course, students will

- understand the basics of mathematical modeling. From physical problem differential equation
- have a working knowledge of scientific computing to make informed choices for simulation
- be proficient in the underlying mathematics
- develop skills in data-driven modeling

Course Content

1. Basic Computational Methods
    a. Solution of linear and nonlinear systems
    b. Calculus and Optimization
2. Ordinary Differential Equations
    a. The Initial Value Problem
    b. Computational simulation
3. Differential Modeling
    a. Climate Change
    b. Epidemiology
    c. Examples with data
4. Mechanistic Modeling
    a. Particle Mechanics
    b. Electrical Engineering
    c. Examples with data

Examples with data

These sections use optimization techniques to estimate ODE model parameters to fit data. Examples will be selected from problems of current interest.

Bibliography

1. Fässler, A. (2019). *Fast Track to Differential Equations*. Springer International Publishing.
2. Dattner, I. (2021). Differential equations in data analysis. *Wiley Interdisciplinary Reviews: Computational Statistics*, *13*(6), e1534.
3. Lynch, S. (2018). Dynamical Systems with Applications using Python. Birkhäuser

Grading

1. Homework (30%)
2. Two written reports on study cases of Differential and Mechanistic modeling (40%)
3. An extended written report and oral presentation of an integrative project (30%)