Data-driven Dynamic Modeling

Intensive Short-Courses

Instructor:
Dr. Miguel Ángel Moreles Vázquez
e-mail: moreles@cimat.mx
Office: K321

Hours:
45 hours

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:

On completion of the course, students will

- understand the basics of mathematical modeling. From physical problem to differential equation
- know the properties of numerical methods to make informed choices for the solution
- be proficient in the underlying mathematics
- develop skills in data-driven modeling

Overall requirements:

- Your intended major should include components involving Mathematics, Statistics, Data Science, or Computer Science.
- At least one matrix algebra course and a single and multivariate variable calculus course (linear algebra course is recommended but not required)

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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. Numerical Methods
3. Differential Modeling
   - a. Population models
   - b. Epidemiology. SIR models
   - c. Ecology. Competitive species
   - d. Examples with data (*)
4. Mechanistic Modeling
   - a. Particle Mechanics.
   - b. The harmonic oscillator.
   - c. Electric Circuits
   - d. Examples with data (*)

(*) In these sections, optimization techniques are used to estimate ODE model parameters to fit data mostly from the literature. An exemption is the harmonic oscillator, presented as a model of the insulin-glucose regulation system. Parameters are estimated from data collected in a local hospital.

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Grading:

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

Bibliography:

- Braun, M., *Differential Equations and Their Applications* (1993)
- Johansson, R., *Numerical Python Scientific Computing and Data Science Applications with Numpy, Scipy and Matplotlib*; 2nd Edition; Academic Press (2019)
- Lynch, S., *Dynamical Systems with Applications using Python*, Birkhauser (2018)
- Quarteroni, A.,Sacco, R., Saleri, F., *Numerical Mathematics*, Springer (2000)