Karlsruhe Institute of Technology

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Master seminar in the summer term 2026

Learning of dynamical systems

In this seminar, we are concerned with learning task to find for given data, a dynamical control system of the form

$$\begin{cases} \dot{x}(t) = f(t, x(t), u(t)), \quad x(0) = x_0 \\ y(t) = g(t, x(t), u(t)) \end{cases} \tag{1}$$

with input function $u\colon [0,\infty) \to \mathbb{R}^m$. The variables $x(t) \in \mathbb{R}^n$ and $y(t) \in \mathbb{R}^m$ are referred to as the *state* and *output* of the system. In the linear time-invariant case, the dynamical system (1) reduces to

$$\begin{cases} \dot{x}(t) = Ax(t) + Bu(t), \quad x(0) = x_0 \\ y(t) = Cx(t) + Du(t) \end{cases} \tag{2}$$

with given matrices A, B, C, D. In this case, the goal is to find these matrices from data. The data we consider in this seminar could either be time-domain data, i.e., samples of the state at selected time instances. Alternatively, it can be measurements of the so-called transfer function, which is obtained by applying the Laplace transform to (2). Assuming a zero initial value, the transfer function for (2) is given as $H(s) = C(sI_n - A)^{-1}B + D$, and the learning task can be formulated as an approximation problem with rational functions.

Neural networks offer a flexible, data-driven approach to learning dynamical systems (1) directly from observed trajectories, without necessarily requiring explicit governing equations. They can capture non-linear state evolution, latent dynamics, or operators (e.g., Koopman) and naturally handle high-dimensional, noisy data. This makes them a powerful tool for prediction, system identification, and control of complex systems, albeit with limited interpretability in terms of traditional mathematical approximations.

In this seminar, we discuss several algorithms from the literature to deal with the task of identifying a dynamical system from data.

Introductory meeting: Monday, February 9 2026 at 13:15, Building 20.30, Room: 3.061. For organizational purposes, we kindly ask you to express your interest in participating by sending an email to `mattia.manucci@kit.edu`.

Prerequisites: Sound knowledge of numerical mathematics. Programming skills (Matlab, Julia, Pyton) may be useful but not necessary.