SUPERVISOR MODULE

DATA-DRIVEN MODELLING OF NONLINEAR DYNAMICS: FROM SPARSE TO LOW RANK

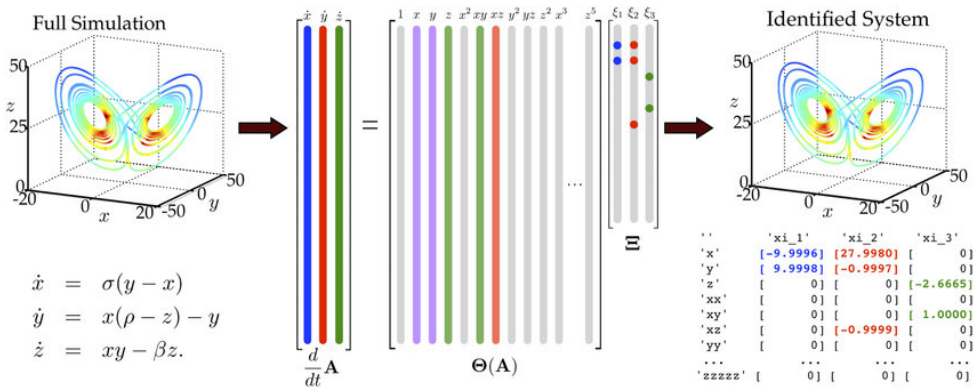
Details Studenten

This thesis concerns an important application of sparse approximation known as Sparse Identification of Nonlinear Dynamics (SINDy). The method identifies the governing equations of a dynamical system from observed time-series data by assuming that the system's dynamics are sparse in a high-dimensional function space. With a dictionary of candidate functions, such as polynomials and trigonometric terms, meant to represent possible terms in the governing equations, it uses sparse approximation techniques to select the most relevant terms, ensuring a balance between accuracy and model simplicity. This approach enables the discovery of human-interpretable, data-driven models and it does so by solving a linear set of equations under sparsity constraints.

As we aim to identify nonlinear systems, the dictionary used in SINDy is constructed using monomials of the basis *x_1,x_2,x_3,...* and functions of those monomials. Example elements from the dictionary include *x_1 x_2^2* and *sin(x_1 x_2^2)*. A key challenge that SINDy faces is the curse of dimensionality. This curse arises because the number of monomials, for a fixed number of basis elements n, grows exponentially with the monomial degree d as *O(d^n)*. Consequently, the dictionary used in SINDy can become very large and the computation expensive.

A second key challenge that SINDy encounters is the choice of the function dictionary and the coordinate basis. Without appropriate choices, SINDy fails to model the data, as the sparsity of the representation is lost under basis transformations. Currently, the coordinate basis and function dictionary are determined by experts in the field of application. This limits the applicability of the technique. By way of example, let us mention "discrepancy modeling", where the goal is to capture effects such as friction and other nonlinearities. Selecting an appropriate basis for such effects beforehand, as currently done in SINDy, is challenging if not impossible.

The goal of this thesis is to break the curse of dimensionality by replacing the sparsity constraint by a low-rank constraint. At the same time, the low-rank approach will eliminate the basis selection problem.



Data-driven identification of a Lorenz system. SINDy sparsely approximates the dynamics in a chosen dictionary of basis functions. (Figure taken from S.L. Brunton, J.N. Kutz, "Methods for data-driven multiscale model discovery for materials," Journal of Physics: Materials, 2(4), 044002, 2019.)

Bijlagen

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VOEG TOE

Promotoren	Co-promotoren	Mentors	Assessoren
Lieven De Lathauwer			

Project URL

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Naam organisatie / URL

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Opmerkingen

Depending on the interest, the emphasis can be put less or more on applications, numerical aspects or implementation. Contact moments are both possible on Campus Leuven (ESAT) and Campus Kortrijk (Kulak).

Wiskundige ingenieurstechnieken

Mathematical Engineering

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