Learning & Adaptive Systems

ETH zürich

Deep Dynamics Learning For Thermoacoustics

Project Proposal for Master Thesis

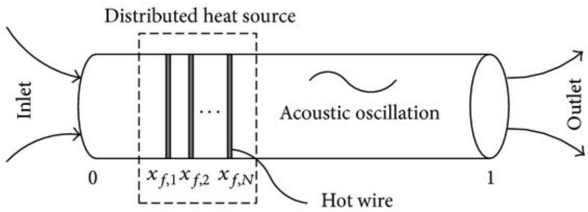

Figure 1: Schematic of the Rijke tube

Motivation: Constructing models from observed data to be able to describe sufficiently well a given system is the key goal of system identification. Properly identified models are invaluable for many down-stream tasks, including system design and control. While linear system identification has reached full maturity with regards to theoretical guarantees and reliable tools, the nonlinear counter part is far less understood. When building non-linear models, one could rely on classical engineering or physics principles, but one can also try to learn them directly from a data set containing many past observations. A promising direction of the second category is centered around deep neural ODEs [Chen et al., 2018], where the underlying differential equations of the system are modeled explicitly using a neural network.

Challenge: Thermoacoustics studies systems dominated by dynamic interaction between pressure waves and heat transfer. The Rijke tube (see Fig. 1) is a thermoacoustic resonator often used as a laboratory test bed of thermoacoustic instability. It exhibits a rich nonlinear dynamic behavior, featuring Hopf bifurcation points, multistable attractors and limit cycle oscillations. This variety of behaviors and inherent nonlinearity of the system makes it difficult to model with traditional system ID approaches. Moreover, due to periodicity in the system and multistability, aspects of identifiability and input design, which are well understoon in linear identification, should be carefully reconsidered here.

Scope: In this thesis, you will expand the classical neural ODEs and combine them with various insights from physics and system identification. From prior knowledge of the system, it is known that the current flowing into the coil represents a fundamental parameter driving the nonlinear response, and one of the goals will be to capture this in the model. All results can be validated on our in-house setup, consisting both of a numerical solver (able to provide synthetic data) and an experimental test bed. This will allow training data to be generated in different conditions, and thus the aforementioned identifiability and input design problems to be investigated.

We are looking for motivated students with a strong mathematical or programming background. We do have some concrete ideas on how to tackle the above challenges, but we are always open for different suggestions. If you are interested, please send an email including your transcripts and CV to Philippe Wenk.

This project will be supervised by Prof. Andreas Krause (`krausea@ethz.ch`), Dr. Stefan Bauer (`stefan.bauer@tuebingen.mpg.de`), Dr. Andrea Iannelli (`iannelli@control.ee.ethz.ch`) and Philippe Wenk (`wenkph@ethz.ch`).

image source: Yang et al. [2015]

References

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Xiaochuan Yang, Ali Turan, and Shenghui Lei. Thermoacoustic instability in a rijke tube with a distributed heat source. *Journal of Thermodynamics*, 2015:1–9, 10 2015. doi: 10.1155/2015/949384.