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System identification for control and dynamical system analysis - wavepackets in turbulent jets as an example

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In this talk, we discuss the application of system identification in turbulent flows for control-oriented modelling and dynamical system analysis. We start by introducing the *N*onlinear *A*uto-*R*egressive e*X*ogenous with *M*oving *a*verages (N-ArMaX), following the footsteps reported in Billings [1] and Guidorzi [3]. A quick overview of the algorithms adopted for the model estimation is proposed.

The introduced concepts are discussed considering as an example the turbulent jets. Recent comparisons between theory, experimental measurements and numerical simulations confirmed that the average characteristics of the coherent structures in the near-field are well described by linear and nonlinear solutions of the Navier-Stokes equations. These solutions are commonly referred to as *wavepackets* and exhibit a remarkable spatio-temporal organisation, as shown by Breakey et al. [2]. Starting from the latter contribution, we consider the pressure measurements associated to these structures, extracted along the streamwise direction from an experimental, iso-thermal jet issuing at $Ma=0.6$ and Reynolds number $Re=5.7 \times 10^5$.

The measurements in time of the pressure fluctuations – referred as *time-series* – are used as inputs and outputs of the models identified by applying the N-ArMaX algorithm. In particular, we will attempt at clarifying the nature of the non-linearities appearing in the temporal behaviour using output-only surrogate models. Finally, we will analyse control-oriented input-output models and discuss the most appropriate strategies of control (Semeraro et al. [4]).

The main goal of the contribution is to assess the extent to which the computed models are appropriate for description of the temporal wavepacket dynamics and to provide a complementary perspective to the wavepacket modelling. In the remainder of the presentation, we will briefly comment on the current development of system identification within the broader field of machine learning.

REFERENCES

[1] Billings, Nonlinear system identification: NArMaX methods in the time, frequency, and spatio- temporal domains, John Wiley & Sons, 2013

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[4] Semeraro et al., Qualitative dynamics of wavepackets in turbulent jets, PRF *under consideration*, 2016

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