Closed-loop turbulence control using machine learning [1]

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Active turbulence control is a rapidly evolving, interdisciplinary field of research. In particular, closed-loop control with sensor information can offer distinct benefits over blind open-loop forcing. The range of current and future engineering applications of closed-loop turbulence control has truly epic proportions, including cars, trains, airplanes, jet noise, air conditioning, medical applications, wind turbines, combustors, and energy systems. Problems of the ISTA and SFB 1029 belong to this portfolio.

A key feature, opportunity and technical challenge of closed-loop turbulence control is the inherent nonlinearity of the actuation response. For instance, excitation at a given frequency will affect also other frequencies, a phenomenon which is not accessible in any linear control framework. We propose a novel nonlinear control strategy with reduced-order modelling (ROM) for known actuation mechanisms and machine learning techniques for discovering unknown mechanisms. First, successful studies for drag reduction of a bluff body and lift increase of an airfoil are reviewed. Then, a novel machine learning control (MLC) method is presented. This strategy has significantly outperformed existing model-based control strategies for analytical examples, numerical simulations and a number of experiments. The experiments include the TUCOROM mixing layer control demonstrator (PPRIME, Poitiers), separation control over backward facing step (PMMH, Paris) and separation control of a turbulent boundary Layer (LML, Lille). We envision numerous MLC applications for the control of complex nonlinear systems.

BIO: Bernd NOACK develops closed-loop flow control solutions for cars, airplanes and transport systems — in an interdisciplinary effort with dedicated colleagues, PostDocs and PhD students at Institute PPRIME (Poitiers, France) and with the groups of Profs. M.W. Abel, J.-L. Aider, S. Brunton, H.-C. Hege, S. Krajnović, M. Morzyński, R.K. Niven, B. Protas, C.W. Rowley, M. Schlegel, M. Stanislas and industry. He is Director of Research CNRS at Institute PPRIME and was awarded with an ANR Chair of Excellence. He has co-authored over 150 publications, 2 patents and 1 book on ROM and flow control. His work has been honored by numerous awards, e.g. a Fellowship of the American Physical Society.

Subset of the turbulence control team at the TUCOROM wind-tunnel. From top left to bottom right: S. Brunton, V. Parezanovic, J.-C. Laurentie, M. Segond, T. Duriez and B.R. Noack.

[1] The talk comprises joint work with Markus Abel, Steven Brunton, Rudibert King, Marek Morzyński, Robert Niven, Michael Schlegel, Marc Segond, Poitiers' TUCOROM Team (Jean-Paul Bonnet, Jacques Borée, Laurent Cordier, Joël Delville, Thomas Duriez, Eurika Kaiser, Vladimir Parezanovic and Andreas Spohn) the PMMH Team of J.-L. Aider and the LML Team of M. Stanislas.

[2] `http://BerndNoack.com`