

Application of “data-driven” methods to physical modelling and sound synthesis of wind musical instruments

Supervisors

Vincent Fréour (Yamaha R&D division & LMA (UMR CNRS 7031))

Christophe Vergez (CNRS senior researcher, LMA (UMR CNRS 7031))

Bruno Cochelin (Professor, Ecole Centrale Marseille, LMA (UMR CNRS 7031))

Place of internship

Laboratoire de Mécanique et d'Acoustique, LMA

4 impasse Nikola Tesla, 13013 Marseille, France

Online meetings with Yamaha corporation (Japan) will be organized during the internship

Candidate profile: student currently enrolled in a Master or PhD program

Duration: up to 6 months

Gratification: about 600 EUR/ month

Language: English and French

Contact

vincent.freour@music.yamaha.com

Description

Sound simulation by physical modelling relies on the representation of the physics underlying the functioning of musical instrument. It constitutes a very interesting tool to simulate the variety of behaviors of the instrument (applications in sound synthesis), and also a very useful tool for musical instrument makers in order to better understand the influence of the different design parameters on the response of the system (sound quality, intonation, transients, etc.). Indeed, using such technology, the instrument designer can investigate numerically the consequences of changes in the conception on the response of the instrument, without having to build a physical prototype. This numerical aid is therefore suitable to investigate various design choices.

However, to develop such models, complex physical phenomena need to be taken into account, from the mechanical behaviour of the musician's lips, to the nonlinearities of acoustic propagation in the resonator, to the coupling modalities between the lips and the air column. In this context, relatively recent data-driven modelling methods offer very promising prospects and an alternative to more “classical” modelling approaches.

This approach relies on a combination of techniques that promote parsimony and machine learning methods, in order to identify the physical equations governing the system dynamics from measurements.

In addition, the use of experimental systems such as “artificial musicians” or “artificial mouths”, developed at LMA and in Yamaha's laboratories, offer particularly well-suited experimental supports for providing the data needed to implement these new modelling approaches. These systems make it possible to “play” the instruments under controlled conditions, and to measure a number of physical quantities (pressures, lip displacement, etc.) that are difficult to access on a musician.

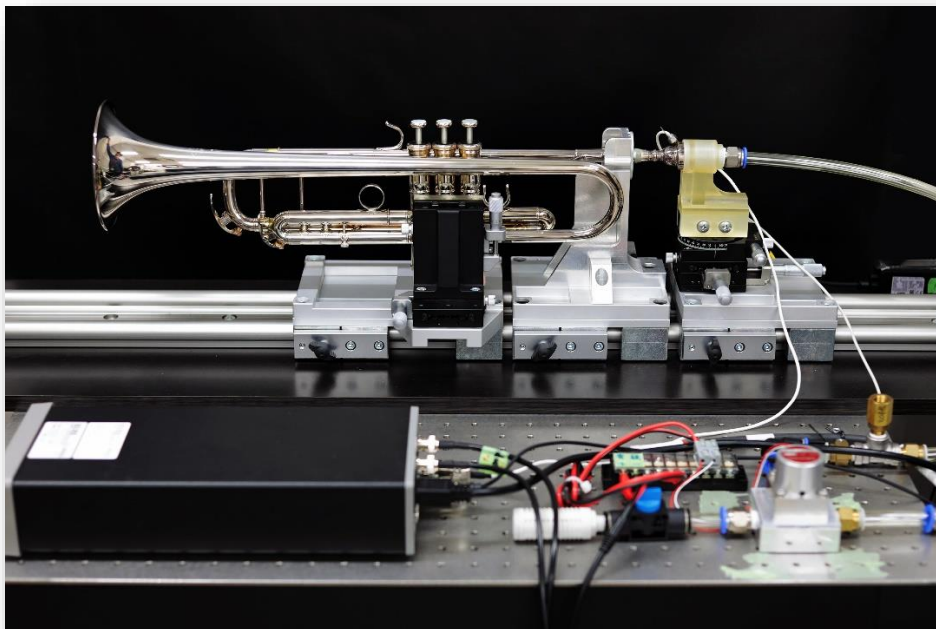


Figure 1. Artificial player system for the trumpet

Following on from initial work started in 2024 on this theme, the aim of this project is to study the performance of data-driven system identification techniques, with the aim of identifying numerical trumpet models using experimental data collected on an artificial player system recently developed at the LMA.

The work will be organized in three stages:

- 1- Explore different regression and machine learning algorithms for the identification of nonlinear systems using data generated numerically (simple nonlinear systems, simple models of wind instruments)
- 2- Conduct measurement campaigns on the artificial player developed at LMA, in order to collect experimental data that will feed the identification algorithms. This work will require the implementation of optical lip measurements, synchronized with pressure measurements, in close collaboration with LMA engineers.
- 3- The model identified in step 2 will be evaluated in two phases: the “validation phase” will quantify the discrepancy between the model and the data used in the learning phase, while the “testing phase” will assess the model's generalizability by confronting it with novel experimental results corresponding to experimental parameters not used when generating the learning data.

Depending on progress, an application phase will aim to:

- 1- Evaluate the benefits of these methods for objective trumpet categorization, with a view to providing Yamaha engineers with tools to help them in the design of new instruments.
- 2- Evaluate the benefits for sound synthesis, with a view to proposing new algorithms for real-time trumpet sound synthesis.

This internship is offered in the context of the NAMI (Numerically Aided Musical Instrument Design) industrial chair established between Yamaha Corporation of Japan, LMA and Ecole Centrale Marseille.

[1] S. Brunton, J.L. Proctor, J.N. Kutz, Discovering governing equations from data: Sparse identification of nonlinear dynamical systems, Proc. Natl. Acad. Sci. USA, 113 (15), 2016.

[2] V. Fréour, L. Guillot, H. Masuda, S. Usa, E. Tominaga, Y. Tohgi. Numerical continuation of a physical model of brass instruments: Application to trumpet comparison, Journal of the Acoustical Society of America, 148 (2), 2020.