Pafi: a Collaborative Musical Instrument Manufacturing Platform

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Introduction

General Context

The French instrument-making economics represents 2400 companies, 2/3 of which only welcome one employee, a total of around 11000 people, a worldwide exported production rate of 80% and a turnover of €800 million / year.

These figures notwithstanding, the sector faces many challenges, viz. constraints on the supply of certain types of exotic woods, or ensuring an appropriate quality-price tradeoff, hence the craftsmen do not always have the means to embark on innovation strategies.

The instrument manufacturing aid platform presented here aims to tackle these challenges at a low cost for the professional. The platform is based on the Python language and deployed as a web-based application. The goal of this platform is to endow the instrument makers with the means to characterize instruments, analyze sounds and develop instrument models.

For the time being, the Pafi platform supports woodwind and brass wind instruments. When designing a wind instrument, a craftsman is commonly mostly interested in tuning, timbre and ease of playing. To be able to account for these features, makers often build many prototypes, to be able to choose the proper instrument dimensions. The Pafi platform helps the makers simulate the construction of the prototypes.

Some tools dedicated to input impedance calculation or measurement exist, but they either allow only for brass wind instruments analysis (such as the BIAS/VIAS software suite provided by ARTIM: `http://artim.at/?page_id=2&sprache=2`) or are not easily usable for instrument makers (ARTOOL, available as a C++ library and API for simulating instruments: `http://artool.sourceforge.net/`).

Unlike these other efforts, the Pafi platform is designed to be a real user-friendly application, close to the craftsmen and musical acoustics researchers.

Why Python?

The large amount of freely-available libraries (e.g. NumPy and SciPy) or web development frameworks provides a very convenient programming environment, in both research and industrial contexts.

Thus, the scientific community could really improve the algorithms and data processing of the Pafi platform. Another objective is to allow the users to share their products in an easy way, thus building a community of craftsmen and researchers. The Pafi software is constantly evolving, always trying to improve the flexibility and maintainability of the system.

The computational and interface parts alike are based on Python, using NumPy and SciPy for the acoustics part, and the CubicWeb framework for the user interface part.

The Pafi Platform: Overview

The Pafi application concerns woodwind and brass wind instruments. It enables –among other possibilities– the measurement and calculation of a designated instrument input impedance. A description of an instrument bore and fingerings is therefore provided on the software. This computer-aided design allows the makers to appreciate and test several geometries without taking the pain to support the production of many prototypes.

Timbre, tuning and ease of playing can –at least partially– be qualified using input impedance analysis, where:

$$\text{input impedance} = \left(\frac{\text{acoustic pressure}}{\text{acoustic flow}}\right)_{\text{at the input of the instrument}}.$$

Thanks to the tool, the maker may measure and calculate some instrument acoustical properties, as input impedance and other derived quantities.

The Pafi Platform: Innovative Aspects

Collaboration

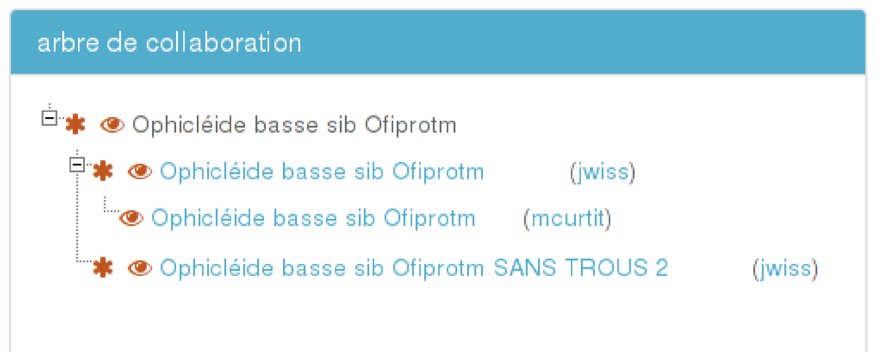
Each user has access to a personal space on the platform. Such an aspect provides a mean to share instruments' geometrical characteristics and other details.

The collaboration feature allows the users to:

- see their own instrument models and those others shared with them
- freeze or unfreeze some instruments models to set them in time
- share instruments with others users
- clone / duplicate some frozen instruments, and to further work on the clones
- trace the evolution of an instrument design displaying a collaboration tree which contains the instrument model and its clones

By contributing to the platform with historical instrument descriptions, museums may thus be offered the opportunity to access and share knowledge.

Here's a collaboration tree involving two users and a Couesnon Ophicleide, year 1900:

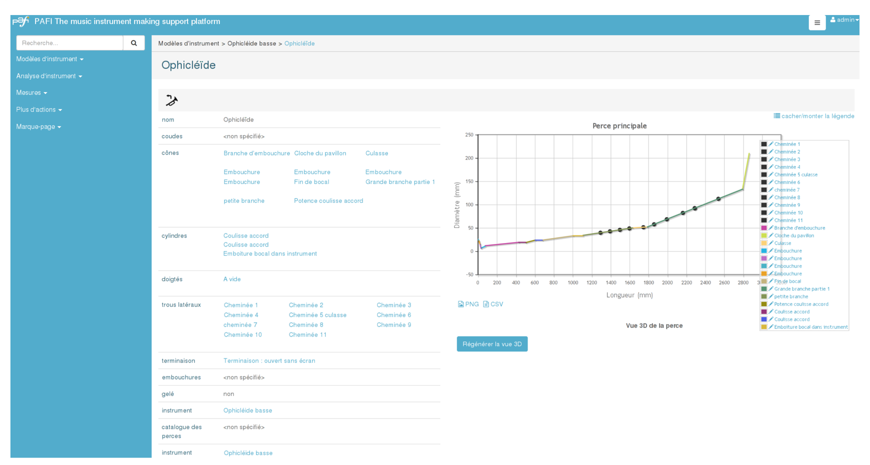


General Bore Geometry Computation and Updating

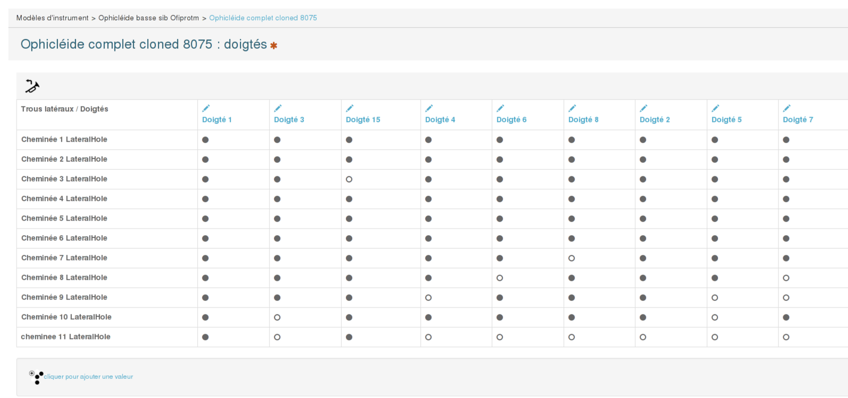
The software allows for computing bore geometries, for instruments with lateral holes and pistons alike. For instruments with pistons computations are particularly involved, as the bore geometry is built of the geometries of the main bore and of the piston bores, the latter depending on the particular fingering being played.

The Pafi platform allows for simulating and investigating several geometrical and acoustical features of the instruments' bores:

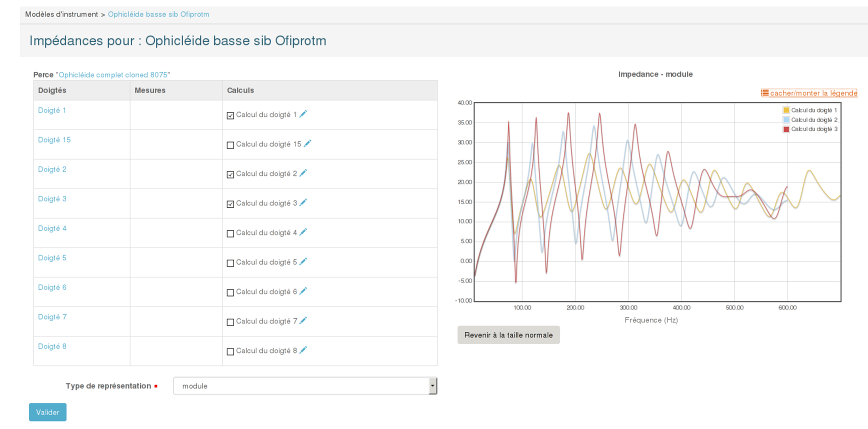
- describing bore geometries; here is one of an Couesnon Ophicleide, year 1900:



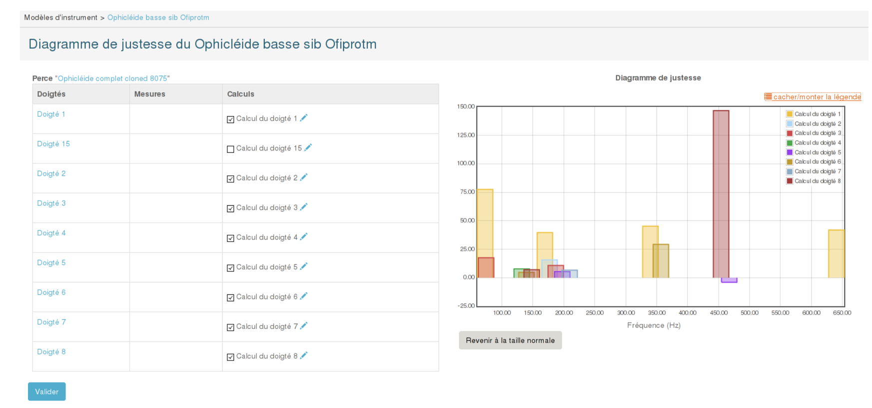
- Defining fingerings (here's one, for the same Ophicleide), including:
  - the lateral hole or piston states (open/closed, engaged/disengaged)
  - the one or several notes played by the fingering



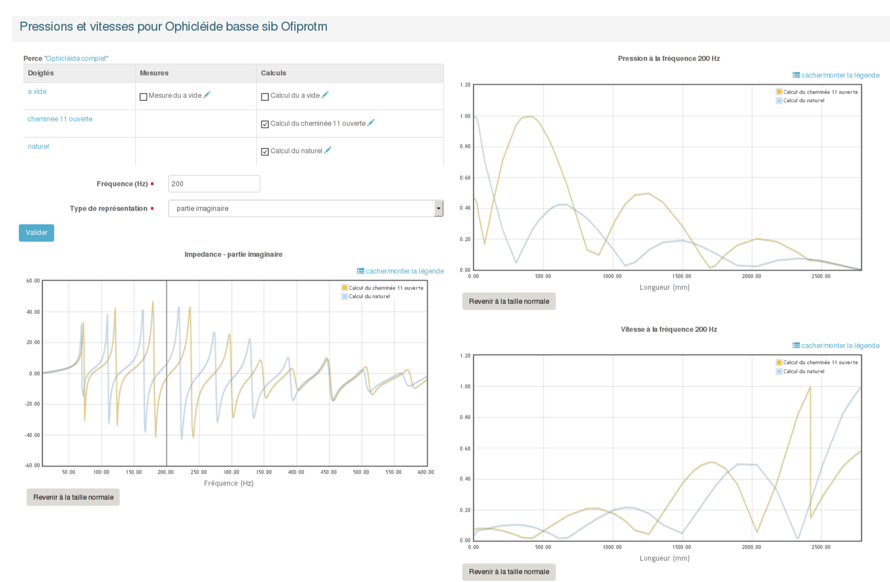
- Computing the input impedance of the main bore of the instrument, for a given fingering:



- Computing the tuning diagram of the main bore of the instrument, for a given fingering:



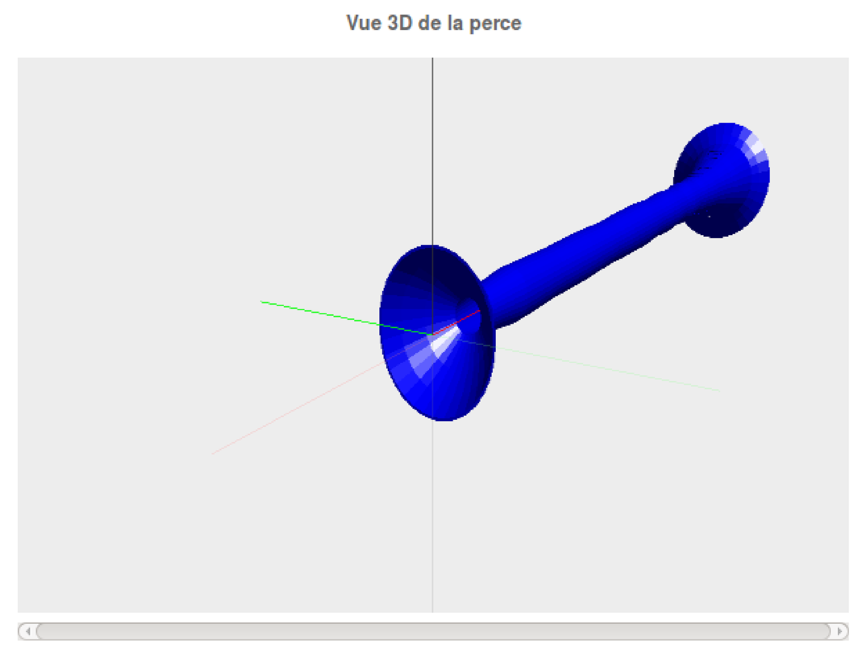
The software also allows for pressure/speed profile calculations, as well as other quantities like reflection functions. Here's a pressure / speed computation for the Ophicleide, at a 200 Hz frequency:



The application can also communicate with a data acquisition device for capturing acoustic waveforms obtained from a real instrument or a mockup (oscillator and bore). This works by plugging the acquisition device to the client PC, which, via the JavaScript Web Audio API, gets and stores the acquired acoustical signal:

User Friendliness

A specific care was given to the user friendliness of the platform to enable a quick and efficient use. For instance, instrument bores 3D profiles can be visualized and manipulated, by using the JavaScript CSG library (`http://evanw.github.io/csg.js/`). Here's the profile of the Ophicleide main bore:



Conclusions and prospects

A complex computer-aided instrument manufacturing platform has been built as a web application. It supports creating and assessing instrument bore profiles. Users can also share instrument models and collaborate on refining them, via a complex and original cooperative work model, inspired from distributed revision control systems.

In the near future, we have several goals:

- release the code as open source
- make the application accessible, as free in the beginning, then as a web service
- allowing the museums to share some historical instruments characteristics like bores or acoustic measurements
- add export features to interact directly with numerical control machine
- add other modules concerning stringed-instruments making and bow making communities.

Acknowledgements

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