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OSCILOS_brass: an acoustic solver for brass instruments

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Software

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Summary

The sound, or timbre, of musical instruments is governed by the distribution of their modal frequencies. In brass instruments like the trumpet, french horn and trombone, the geometry of the internal bore is the principal factor determining the modal frequencies. Harmonic analysis of brass instruments is necessary to assist bore shape optimisation by instrument makers, and to enable research into lip dynamics, the origins of 'brassiness,' and other prevailing questions in brass wind acoustics. OSCILOS_brass provides an easy-to-use platform for determining the modal frequencies of a given instrument geometry, be it trombone or drainpipe.

Statement of need

OSCILOS_brass is intended as a tool to assist brass wind acoustics research, allowing the effects of nuances in instrument geometry on sound and playability to be explored. OSCILOS_brass is based on OSCILOS_long (Li et al., 2017), an open source code for simulating combustion instabilities, whose predictions have been validated against experiments (Han et al., 2015; Xia et al., 2019). OSCILOS_brass is written in MATLAB, is highly modular, and is straightforward to run and edit. It represents an instrument bore as a sequence of connected cylindrical finite elements, using a 1-D plane wave approximation. A variety of inlet and exit acoustic boundary conditions are available, including open, closed, Levine-Schwinger and user-defined boundary conditions. The mean flow is calculated assuming 1-D flow conditions, with changes only across element interfaces. Extensive documentation is provided in the accompanying technical report and user guide (MacLaren et al., 2021).

A typical tenor trombone geometry is shown in Figure 1.

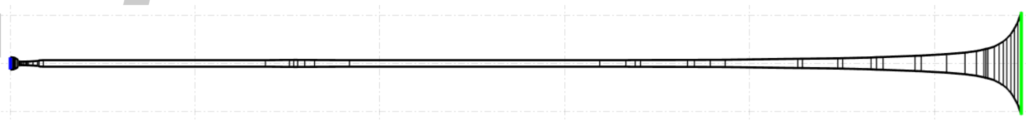

Figure 1: Trombone bore profile from (Bilbao & Chick, 2013) as represented by OSCILOS_brass.

OSCILOS_brass calculates Equivalent Fundamental Pitch (EFP) deviation defined by Equation 1 (Chick et al., 2004), where f_i is the frequency of the ith mode, and F is the reference fundamental pitch, conventionally taken as $f_4/4$, the note to which brass players often tune their instruments. The unit of this definition is the `[cent]`, equal to $1/100$th of a semitone, or a frequency ratio of $\sqrt[1200]{2}$.

$$\mathrm{EFP}(f_i) = \frac{1200}{\log(2)} \log\left[\frac{f_i}{iF}\right] \quad (1)$$

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Good agreement with published measurements and simulations for this geometry, and for a tuba geometry from a separate study (Norman, 2013), is demonstrated in Figure 2.

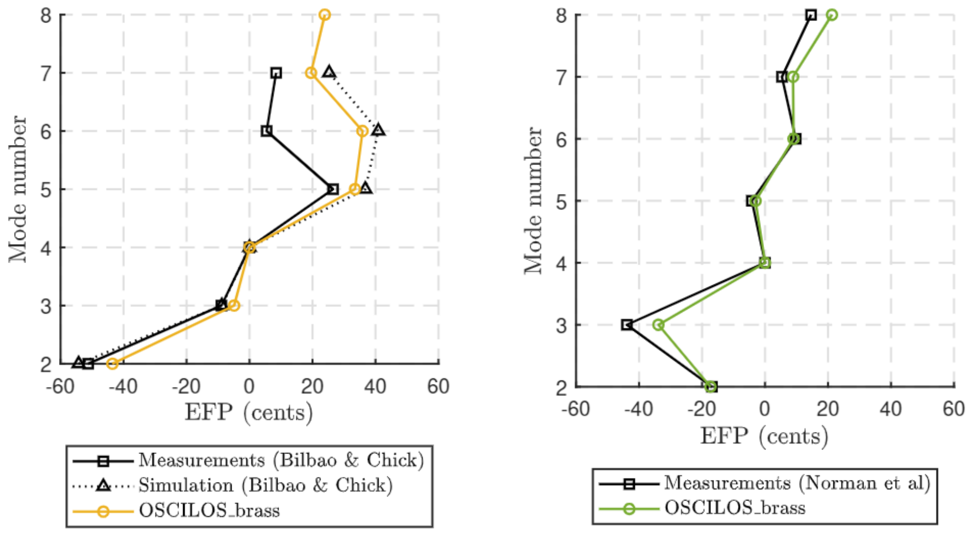

Figure 2: OSCILOS_brass EFP comparison to results for trombone geometry from (Bilbao & Chick, 2013) (left), and to results for tuba geometry from (Norman, 2013) (right).

EFP is shown for 4 combinations of boundary conditions in Figure 3, as calculated for the trombone geometry in Figure 1 by OSCILOS_brass.

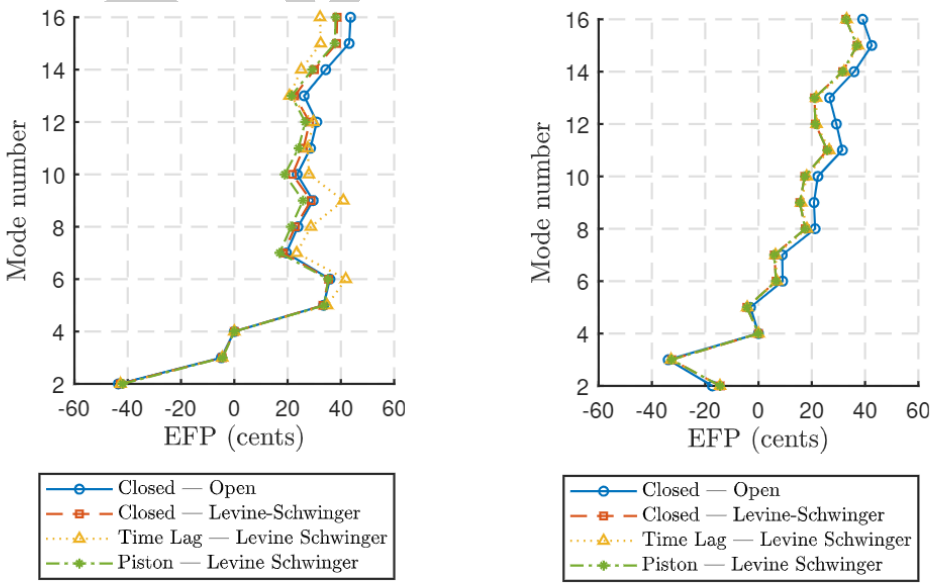

Figure 3: EFP output by OSCILOS_brass for 4 [Inlet - Outlet] sets of boundary conditions applied to the trombone geometry from (Bilbao & Chick, 2013) (left), and to results for tuba geometry from (Norman, 2013) (right)

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