WIND INSTRUMENT ACOUSTIC RESEARCH IN THE COMPUTATIONAL ACOUSTIC MODELING LABORATORY, MCGILL UNIVERSITY

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1. INTRODUCTION

The Computational Acoustical Modeling Laboratory (CAML)[1] of the Music Technology area, Schulich School of Music, McGill University, was established in 2004 by Gary Scavone. Research conducted in CAML includes 1) Studies and measurements to gain a theoretical understanding of the fundamental acoustic behavior of music instruments and other sounding objects, 2) Development of computer-based mathematical models that implement these acoustic principles as accurately as possible, 3) Development of efficient, real-time synthesis algorithms capable of producing convincing sounds (perhaps informed by psychoacoustic data), and 4) Development of appropriate human-computer interfaces for use in controlling and interacting with real-time synthesis models. The laboratory has been funded in large part through a Canadian Foundation for Innovation (CFI) New Opportunities grant awarded in October 2004, as well as an NSERC Research Tools and Instruments grant.

2. SUMMARY OF INVESTIGATIONS

An overview of our recent results, as well as work in progress, is reported in this section with references to submitted and/or published articles.

2.1 Development of input impedance measurement techniques for wind instruments

We recently investigated two methods for measuring the acoustic input impedance of wind instruments. In the first approach, commonly referred to as the two-microphone transfer function method, a tube is connected to the instrument and excited with a broad-band stimulus. Signals recorded at microphone pairs placed along the tube are then analyzed to estimate the instrument input impedance. The second technique, a novel variant of pulse reflectometry, makes use of a long tube with a single microphone located at its midpoint. Using a long-duration broad-band source signal, the impulse response is measured for the tube, first with a rigid termination, and then with the system to be characterized attached. The system reflectance, and therefore its impedance, is found by comparing the first reflection from the tube end for both measurements. (Lefebvre et. al., 2007).

The measurement techniques have been compared for various acoustic systems, including an alto saxophone neck and fabricated conical objects. Both methods show good agreement though there are some discrepancies with theoretical results that might arise from object curvature, under-estimation of boundary losses and temperature fluctuations. Further analysis of these results is planned.

2.2 Comparisons of theoretical and measured impedances of saxophones

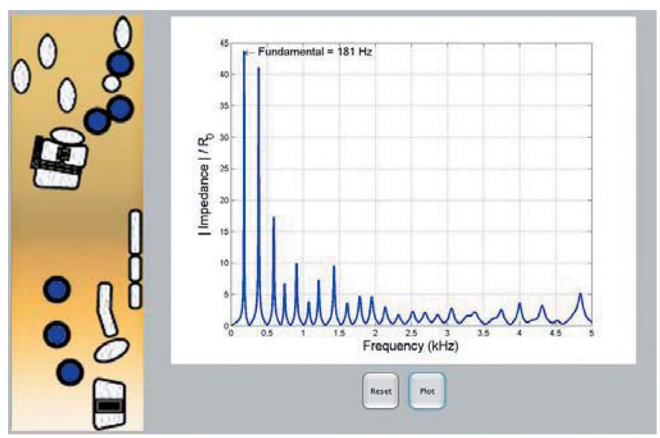

Fig. 1. Saxophone impedance web interface.

A general computational structure has been implemented that allows for the evaluation of the input impedance of an arbitrary acoustic object in terms of cylindrical and conical segments and toneholes (Matthews and Scavone, 2007). A Web-based interface, as shown in Fig. 1, has been created to allow general user access to the computed results for saxophones and comparisons with measurements. By approximating the saxophone's response computationally for different combinations of open toneholes, one can make predictions of the instrument's timbre and tuning. Future work will focus on validating or improving the current

1 http://www.music.mcgill.ca/musictech/caml/

theoretical model of toneholes in conjunction with conical air columns.

2.3 Identification of key features leading to instrument quality

In order to improve woodwind designs, we hope to find correlations between geometric, acoustic, and subjective features of instruments. From that, we hope to determine a set of ideal frequency responses and use an iterative computational approach to find optimized designs. Specifically, we will look at intonation, timber uniformity, ease of response, dynamic range, playing action, etc.

2.4 Study of vocal-track influence in the performance of saxophones

An approach for analyzing vocal-tract influence in single-reed instruments during performance has been developed. The system provides a relative comparison of the upstream windway and downstream air column impedances under playing conditions and a visual display that allows players to investigate the effect of vocal-tract manipulations in real time. The measurement approach assumes continuity of volume flow on either side of the reed, which leads to a direct proportionality between the upstream and downstream pressures and impedances. Playing experiments were designed to explore vocal-tract influence over the full range of the saxophone, as well as when performing special effects such as pitch bending, multiphonics, and "bugling". The results indicate that vocal-tract influence is required when playing in the extended register of the saxophone, as well as when pitch bending notes high in the traditional range of the instrument. Subtle timbre variations via tongue position changes can affect spectral content in the range 500 – 2000 Hz and are possible for most notes in the saxophone's traditional range. Instances of timbre variation are assumed to make use of a wide bandwidth vocal-tract resonance, whereas significant upstream influence involves a narrow bandwidth resonance. An article has been submitted to the Journal of the Acoustic Society of America on this subject.

2.5 Investigation of tonehole design improvements

Traditional woodwind toneholes, when closed, leave a non-negligible volume on the inside of the air column that has a negative effect on the acoustics of the instrument. Current instrument designs include various geometrical corrections to account for this effect. We are investigating a tonehole design in a conical air column that eliminates closed-hole chimney volumes, as illustrated in Fig. 2. The keys are curved to fit the hole shape and are closer to the body to allow the hole space to be filled when the key is closed. Experiments are planned for the theoretical characterization of these toneholes so that calculations can be performed to determine correct positioning and diameter parameters. Possible changes to timbre will also be evaluated.

Fig. 2. Experimental tonehole design without chimney.

2.6 The use of innovative materials and fabrication techniques

The use of composite material for the molding of musical instruments is under investigations. Possible benefits include reduced weight, improved resistance to shock and temperature variations, elimination of discontinuities between sections, increased flexibility on the fabrication of complex shapes (like curved toneholes), etc. Conical objects have been built and their qualities are under investigation.

REFERENCES

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