A Virtual Reconstruction of Trumpet

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Summary: Virtual reconstructions of musical Instruments have been already analysed in past years on violins. The "virtual" instruments can be used in subjective listening tests for the evaluation of the sound quality of different instruments, as well as in the restoration of ancient instruments, and for preliminary listening test on new designed instruments.
In this paper, the trumpet is treated as linear systems, characterised by its impulse responses.
From the IRs measured in different positions in the trumpet, an inverse numeric filter of three trumpets has been obtained, through a new developed technique. From the recording of some original pieces of music, sampled directly inside one of the trumpets, an "anechoic" signal has been obtained, by convolution with the inverse filter calculated in the same position.
The "anechoich" signal, convolved with the IRs just measured in the other trumpets produced a signal containing all the acoustic characteristics of the instruments, avoiding all non acoustic phenomena, and allowed the realisation of "virtual" reconstruction of the trumpet.
The first results of the listening tests confirm the similarity between the direct acoustic recording and the convolution technique also for the trumpet, as well as already found for the violins.

INTRODUCTION

Virtual reconstruction of musical instruments is a simple way to reproduce sound characterization of sound chests or sound boards. As already tested [1], the characterization of musical instruments may be described by measuring IR of the instrument, provided the sound samples should be acquired in anechoic environment, and convolved with the inverse filter of the instrument utilized, calculated in the same position.
That is to say the body of the trumpet may be considered as linear system, while all non linear phenomena of the sound generation, as lip vibrations, are considered just in the recording of the performance.

ACOUSTICAL MEASUREMENTS

The measurements have been conducted on three different trumpets, namely Vincent Bach, tuned in C, Yamaha, tuned in B-flat, and Yamaha Custom, tuned in B-flat at the upper octave. The first two trumpets are quite much alike, while the last one is quite different, both in shape and in sound timbre. The IRs have been measured by using Aurora system in many positions in the bore, inside the instruments, as well as in the flaring bell. A PC equipped with soundboard generated the MLS sequence, fed into a small loudspeaker that has been fixed on the mouthpiece. The measuring points considered in each instrument, covered almost all the bore. They have been chosen with a step of 5 mm each other, beginning from the flaring bell until to reach the cylindrical tube. Some tests have been conducted with different conditions of the trumpets, e.g. weights on the valves.

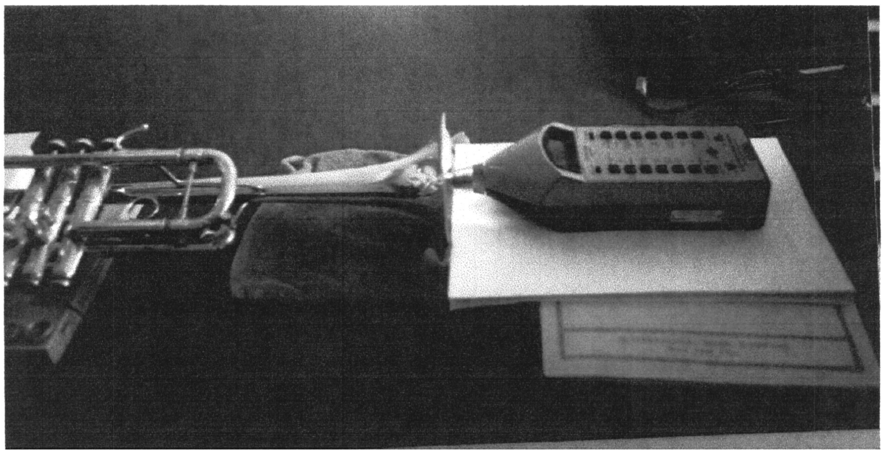

FIGURE 1 Measurements in the trumpet "Vincent Bach", tuned in C

The recordings have been conducted in near acoustic field, close to the trumpet, and the approximate inverse IR have been obtained by meaning of Toeplitz matrix. In a second step, by convolution with the inverse filter, the "anechoic" music has been obtained, and then colvolved with other IRs.

RESULTS

The frequency responses of the trumpets have been calculated from the experimental impulse responses. In a first step, the frequency responses have been compared among the different positions in the flaring bell.

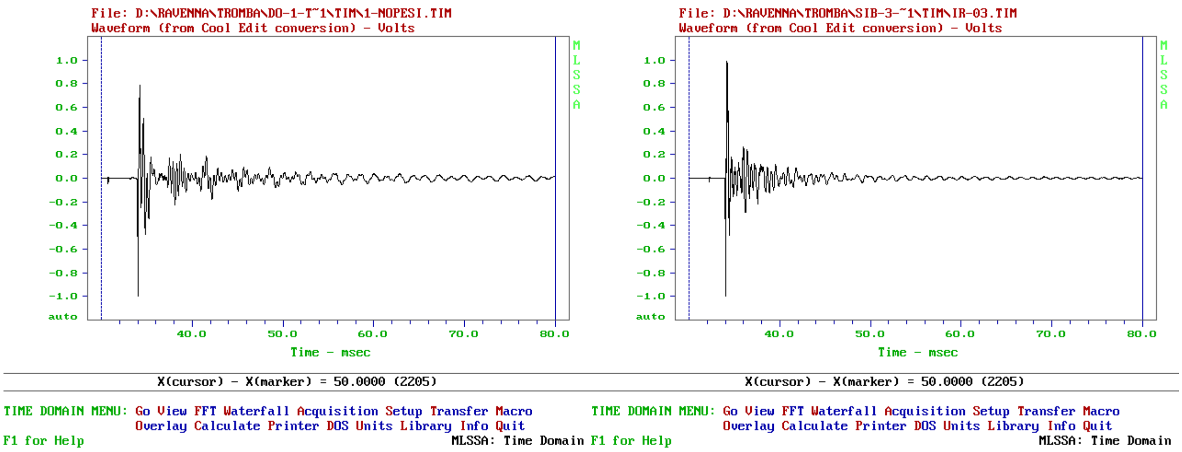

FIGURE 2 Trumpet "Vincent Bach", model 229 C1 (in C) (left) and "Yamaha Custom", model 9830 (in B-flat, upper) (right)

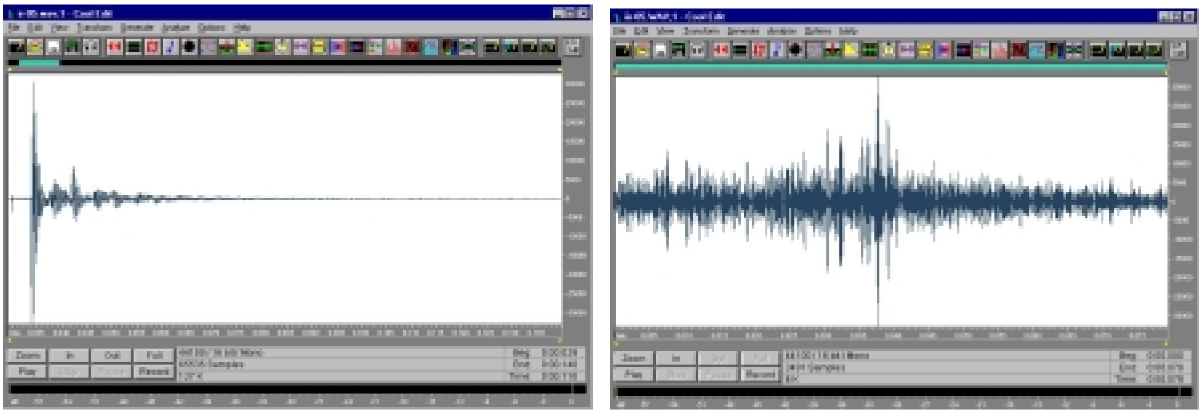

FIGURE 3 Trumpet “Yamaha”, model 6345 HS (in B-flat) IR and inverse filter

FIGURE 4 Yamaha (tuned on b-flat); recorded music (left), after deconvolution (right);
after reconvolution (letf, below) Convolution with Yamaha custom (tuned on b-flat, upper) (right)

Slight differences have been pointed out by making measurements in the trumpets, coming from inside the tube to the flaking bell, in which the frequency responses of the instruments decreased, and by applying weights on the valves.

In a first step the reconstruction of the waveforms have been compared with the original recordings, and the sounds have been listened by a group of hear-trained students at University of Bologna. In a second step, other impulse responses have been used in the reconstruction of the trumpet, and compared each other. The experiment has been conducted also with a quite different kind of instrument, i.e. a flute.

CONCLUSIONS

From the analysis, a slight difference in frequency response has been found especially at the higher frequencies, where the flaking bell sounds more evidently. The reconstruction of sound characterization of the trumpet by using MLS technique gives the possibility of comparing different instruments of different characteristics and/or material, avoiding all non acoustical phenomena, as already found in string Instruments, i.e. violins.

SOUND EXAMPLES

- http://ciarm.ing.unibo.it/researches/trumpet/mahler504.mp3 (Recorded music: "Yamaha", model 6345 HS)
- http://ciarm.ing.unibo.it/researches/trumpet/anec-mahler504.mp3 (Anechoic music: "Yamaha", model 6345 HS)
- http://ciarm.ing.unibo.it/researches/trumpet/mahler504-riconvoluta.mp3 (Reconvoluted music: "Yamaha", model 6345 HS)
- http://ciarm.ing.unibo.it/researches/trumpet/mahler504-riconDO-nocartone.mp3 (Convolution with IR "Vincent Bach", model 229)
- http://ciarm.ing.unibo.it/researches/trumpet/mahl504-ricontrombinoir2-04.mp3 (Convolution with IR "Yamaha Custom", model 9830)
- http://ciarm.ing.unibo.it/researches/trumpet/mahl504-riconflautobundyir-b.mp3 (Convolution with IR of flute

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1. Farina, A., Langhoff, A., Tronchin, L. *Journal of New Music Research*, **27**(4), pp. 359-379 (1998).
2. Fletcher, H. N., Rossing, T. D., *The Physics of Musical Instruments*, Springer-Verlag, 1991 New York.