Gold vs Silver: Does material influence the sound of flutes?

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Introduction

Musicians tend to agree that the material their instrument is made of influences the response and the sound of the instrument. Although investigations are still being made on whether and how the material the instrument is made of could play a role on the sound production and radiated sound of brass instruments, the issue is still under debate among acousticians.

In a preliminary study where two flutes of the same maker and model, differing only on material (one made of gold, one of silver) were played by students at the University of Music and performing Arts, Vienna (presented at the Wind Instrument Symposium 2009 in Edinburgh, Scotland), slight differences in the radiated sound of the two flutes were found. The differences seemed to depend on the experience of the player: Statistically significant differences appeared more often with players who had already had experience playing both gold and silver flutes, than with the player who had only played silver plated ones.

Were the differences found related to the fact that the flutes were made of different material? Or would these differences also be found in two "identical" flutes, since there exist no two exactly identical instruments? This is the question that this study addresses: Would two flutes of the same maker, model and material sound different, due to slight differences in their making?

Methodology

A PhD student from the University of Music and performing Arts, Vienna, (subsequently referred to as VS) was asked to play a tune 25 times with two "identical" Muramatsu flutes model GX (Silver body with silver plated keywork and drawn chimneys), alternating them throughout the duration of the recording. The selected tune was the first 8 bars of the second movement of W. A. Mozart's flute and orchestra concerto D major, KV 314. He played in an anechoic chamber, where the radiated sound of the flutes was recorded using a 1/4" ROGA RG-50 microphone, placed close to his left ear.

Sound processing and analysis

The recorded session was split into segments, each approximately 29.5 seconds long, where each segment was one instance of VS playing the melody.

Each separate segment was analysed using the mqan program that comes with the SNDAN package provided by James Beauchamp/. For detailed information about this program, the reader is referred to [1], [2]. The analysis delivers an analysis file with information about the amplitudes $A_k[n]$ and frequencies $f_k[n]$ of the k peaks that are present at every time frame n. In this case, the time difference between two frames was approximately 1.5 ms, giving a total of just above 20,000 frames per segment.

With the information delivered by the analysis file, the following parameters were calculated for each time frame:

- RMS amplitude:

$$RMS[n] = 20 \cdot log_{10}\left(\sqrt{\sum_{k=1}^{K} A_k^2[n]}\right) \quad \text{[dB]} \quad (1)$$

- Normalised spectral centroid:

$$NSC[n] = \frac{\sum_{k=1}^{K} k \cdot A_k[n]}{\sum_{k=1}^{K} A_k[n]} \quad (2)$$

- Pitch:

$$\mathcal{P}[n] = 1200 \cdot log_2\left(\frac{F[n]}{F_{ref}}\right) \quad \text{[cents]} \quad (3)$$

where:

$$F[n] = \frac{\sum_{k=1}^{5} \frac{A_k[n] \cdot f_k[n]}{k}}{\sum_{k=1}^{5} A_k[n]} \quad \text{[Hz]} \quad (4)$$

and F_{ref} is the frequency in Hz of the tonic D_5 (587.33 Hz in the case of the melody VS played).

Calculations of the RMS amplitude, normalised spectral centroid and pitch vs time for all segments of the two flutes were saved in a file.

Statistical testing

The calculations were divided into two groups: one group corresponding to those of one flute and the other group of the other flute. For each calculation and time frame, a two-sided t-test was performed along the 25 instances with $\alpha = 0.001$, and with the assumption that the variances were not equal (the statistics chosen statistics program approximates the effective degrees of freedom accordingly). The test delivers the test result coded as follows: 1 if $p < \alpha$ and 0 otherwise.

Results

The result of the t-tests for the three calculation files: RMS, normalised spectral centroid and pitch, was zero for all time frames.

Results from a previous preliminary study

It is interesting to show the results of a previous study, where a graduand of the University of Music and performing Arts, Vienna (subsequently referred to as JK), played two Muramatsu flutes: a silver flute model GX with silver plated keywork, a 14 carat gold flute model 14.K with silver keywork – both flutes with drawn chimneys. It is worth noting that the recordings where these results come from were made when the player was blindfolded. The flutes were given to her in random order, each flute 30 times, and she was asked to state which flute she had just played. She was correct 90% of the time. A χ^2 test showed that $p \approx 3 \times 10^{-9}$. The results of the t-tests corresponding to the RMS amplitude are shown in Figure 1, which was where more differences were found: there were two interval of 0.5 to 1 second where the golden flute had a higher amplitude. Shorter differences were also found in the normalised spectral centroid and pitch (between 40 and 100 ms and between 3 and 80 ms respectively). Whether these latter differences are musically significant is unclear, due to their short duration.

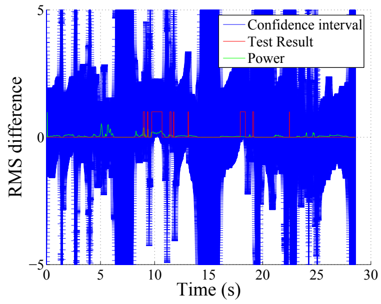

Abbildung 1: Statistics showing differences in the melody's RMS amplitude when subject JK played 2 Muramatsu flutes made of gold and silver in a blind test

Control measurement

To make sure that it was indeed possible to find differences in sound between gold and silver flutes when the subject VS played them, a control measurement was made. This time he played 2 Sankyo flutes: A gold flute model GF 14K 4ST with 14 carat body, silver keywork and soldered chimneys, and a silver flute model CF 401 with silver body, silver keywork and drawn chimneys. For this test, he was blindfolded. He played the first 8 bars of the 6th movement (Menuet) of J. S. Bach's Orchestral Suite No. 2, BWV 1097. He was given the two flutes in random order, and was asked to state every time which flute he had just played. He made no mistakes. The recorded sounds were analysed as before. The most prominent differences were found in the pitch, shown in Figure 2, where the golden flute was up to 30 cents sharper than the silver flute on some notes. Shorter differences were found in the spectral centroid and RMS (between 20 and 60 ms and about 65 ms respectively).

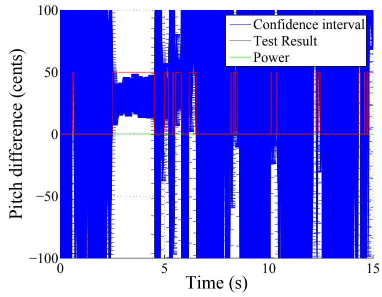

Abbildung 2: Statistics showing differences in the melody's pitch when subject VS played 2 Sankyo flutes made of gold and silver in a blind test

Conclusions

Based on the premise that there can never be two truly "identical" musical instruments, the objective of this work was to investigate whether the differences between gold and silver flutes could be attributed to slight differences in the geometry and manufacture of the flutes, as opposed to the material they are made of. For this purpose, a professional flute player was asked to play 2 "identical" silver flutes. Sound analysis of the recorded sounds and statistics show no differences at all between two silver flutes. This supports the assumption that two "identically" manufactured flutes, differing only in material, do indeed sound different. Studies that involve several flutes and several players need to be carried out, in order to find solid evidence that they do sound different; and if so, the cause of these differences.

Literatur

[1] James W. Beauchamp. Unix workstation software for analysis, graphics, modification, and synthesis of musical sounds. *Audio Engineering Society*, page Preprint 3479, 1993.

[2] James W. Beauchamp. Analysis and synthesis of musical instrument sounds. In James W. Beauchamp, editor, *Analysis, synthesis and perception of musical sounds: The sound of music*, pages 1–89. Springer, 2007.