Empirics of Piano Tuning

Timour Klouche
Staatliches Institut für Musikforschung, Berlin, Germany, e-mail: klouche@sim.spk-berlin.de

Introduction

This article presents an empirical study focused on the piano tuning process performed by professional tuners on concert grand pianos. The analysis involves 28 pre- and post tuning F0 measurements, computation of pitch residue, tuning effects, absolute pitch and selected statistical markers. A more detailed version of the paper will be available online [4].

Setup and Methods

The minimization of external influences to the measurements has been given high priority throughout the inception of our microtonal validation series [1], [2], [3]. We thus applied the very same, already validated and tested experimental setup. The interested reader is directed to the publication [2] for details of the setup including all measurement- and preprocessing parameters. Following is a very brief summary of the steps involved: The complete pitch gamut of a Steinway D concert grand piano is recorded directly before and after the tuning process preparing public concerts in the Curt-Sachs Saal of the Staatliches Institut für Musikforschung in Berlin. Each recording consists of 88 piano pitches in the way that each key is depressed for 6s followed by 6s silence, captured by both, stereo condenser ORTF- and boundary microphones. Subsequently the sound file (2 channel 192 kHz, 24 bit) is monoized, segmented with a MATLAB rms-dependent script and analyzed via PRAAT. The fundamental frequency is calculated with the F0 autocorrelation function of PRAAT (for all details see [2]). A focus on the signal description layer by measuring the fundamental frequencies of piano tones is deliberately chosen and believed to be adequate for empirical tuning research.

Results

Post-tuning A4 pitch

Interestingly, the tuners stated in post-analysis interviews to have chosen a target pitch of 442 Hz. This finding is confirmed by a 2 Hz increment first believed to be an analysis artifact. This measurement series' averaged mean absolute deviation (MAD) for F0 deviation to expectancy calculates to 0.75 Hz or 2.9 cents, respectively. The ranges of measurements are greater for the boundary microphone, reflecting the outlier of measurement No 10, cf. fig. 3. Neglecting this single sample and leaving all other parameters identical, the ORTF measurement setup delivers generally smaller measuring ranges.

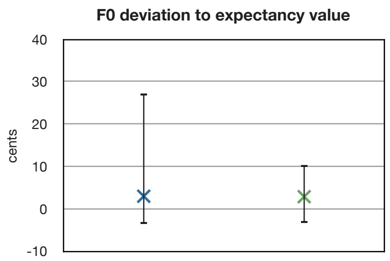


Fig. 1: A4 pitch of 28 distinct fresh piano tunings: Min, max, and mean absolute deviation (x) for boundary mic (blue) and ORTF (green).

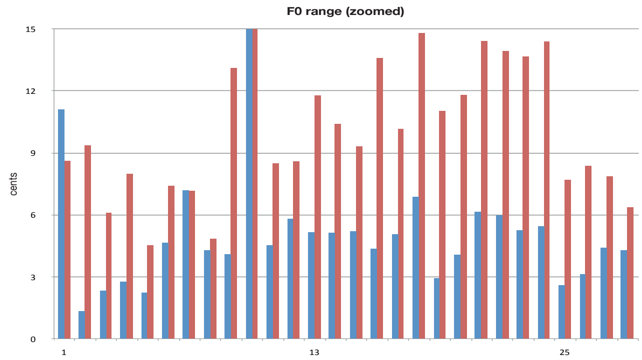


Fig. 2: F0 measurement ranges (zoomed): boundary mic (blue) and ORTF (red) per number of measurement.

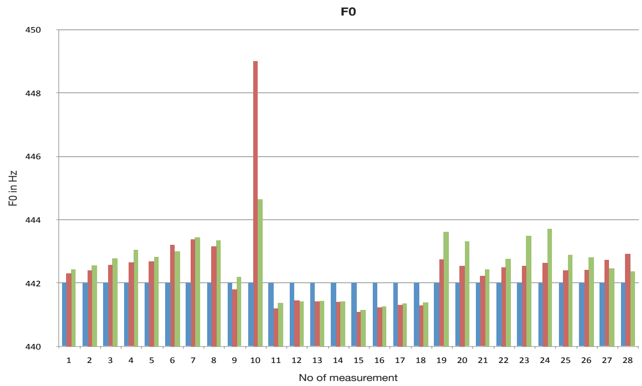


Fig. 3: Averaged F0 measurements per number of measurement: expectancy (blue), boundary mic (red) and ORTF (green).

Pre-tuning F0 measurements

The following graphs depict exemplary measurements (no. 8 of the measurement series; for comparison another measuring sample is given in the annex). This is an analysis of a pre-tuning concert grand piano. While the F0 measurements include some outliers a characteristic curve is revealed in fig. 4. This increment towards extrema and especially in the discant is due to octave stretching effects in that intervals are tuned larger as would expected. The amount of octave stretching of approx. 30 cents confirms once again findings of our last experiments [3] including the comparative validation of real and virtual pianos.

Intra-note ranges measured mostly below 20 cents resulting to an averaged F0 deviancy of approx. 5 cents (cf. fig 5 and 6).

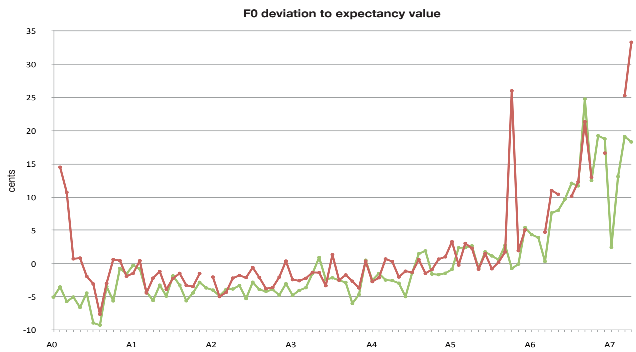


Fig. 4: Measured F0 deviations from reference values in cents: boundary mic (red) and ORTF (green).

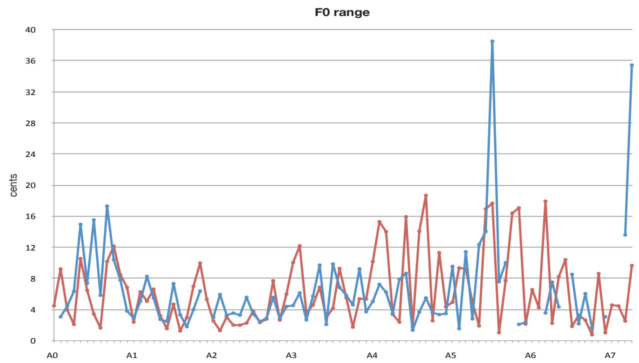


Fig. 5: Measured F0 Intra-note ranges in cents: boundary mic (blue) and ORTF (red)

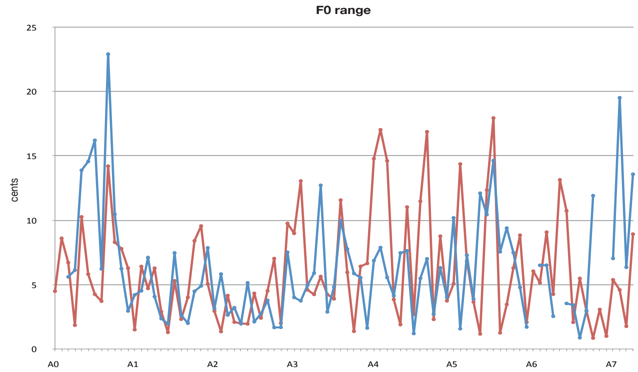


Fig. 8: Measured F0 Intra-note ranges in cents: boundary mic (blue) and ORTF (red)

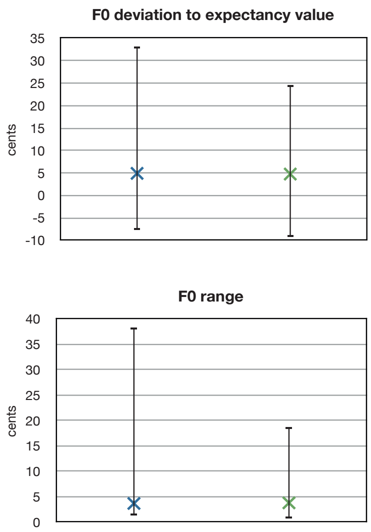


Fig. 6: Min, max, and mean absolute deviation (x) for boundary mic (blue) and ORTF (green).

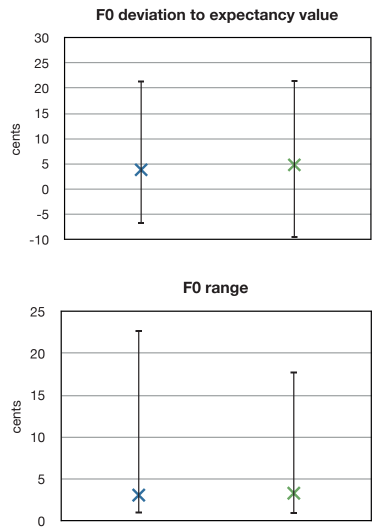


Fig. 9: Min, max, and mean absolute deviation (x) for boundary mic (blue) and ORTF (green).

Post-tuning F0 measurements

The following graphs depict post-tuning results of the very same measurement setup. Most pre-tuning observations also hold true for the post-tuning measurements. The octave stretching effect is clearly visible in fig. 7.
In contrast to the pre-tuned results, both intra-note range and F0 range are statistically smaller but their averaged values.

Tuning residue

The next figure shows the calculated tuning residue, i.e. the difference of pre- and post tuning F0 analysis. Neglecting the outliers that are prominent only in the higher registers, most values are within 4 cents. The residue calculates in the middle octave region A2 to A5 even within approx. 2 cents.
It should be mentioned that the time span between two tunings is generally just two weeks and the instrument is kept in an air-conditioned environment.

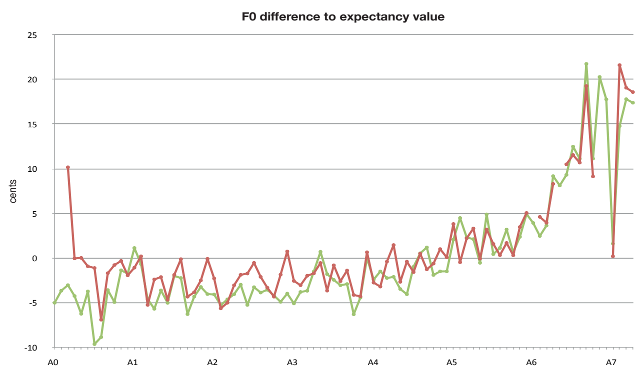


Fig. 7: Measured F0 deviations from reference values in cents: boundary mic (red) and ORTF (green)

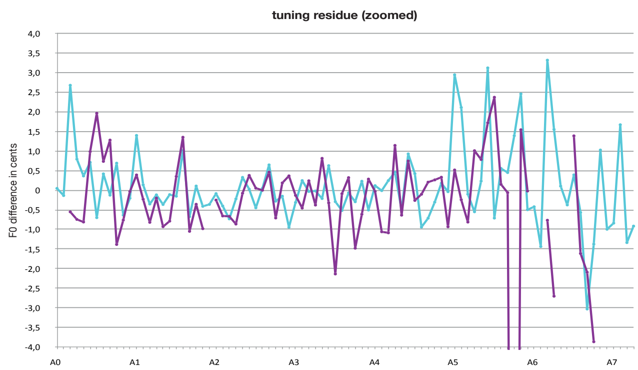


Fig. 10: Measured tuning residue in cents for boundary mic (purple) and ORTF (turquoise).

Tuning effect

A direct comparison and visualization of the tuning process' effect is given in the next graphs. The tuning process' influence on single measured pitches is minimal as mentioned above. Even the octave stretching follows similar characteristics. Statistically, a small improvement towards the expectancy value is observable in the case of the ORTF setup example (fig. 11). In accordance with this finding measuring ranges are smaller in all cases. This would be of interest to the both academic and artistic approaches to piano tuning if this is due to the tuning process itself and warrant further analysis and explication.

Comparing both measuring setups, the measuring ranges are generally lower for the boundary microphone than those for the ORTF. The averaged mean absolute deviation to expectancy value on the other hand is comparable for both.

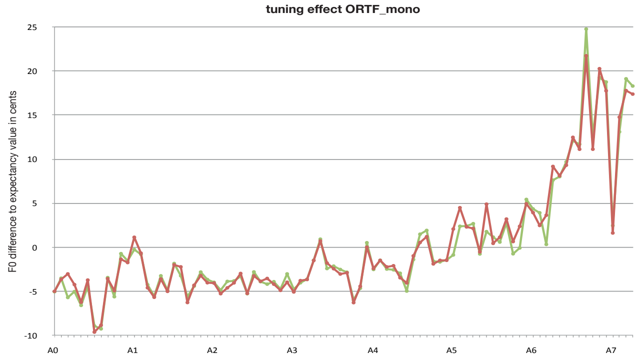


Fig. 11: Measured F0 deviations from reference values in cents for ORTF mic: tuned (red) and pre-tuned (green)

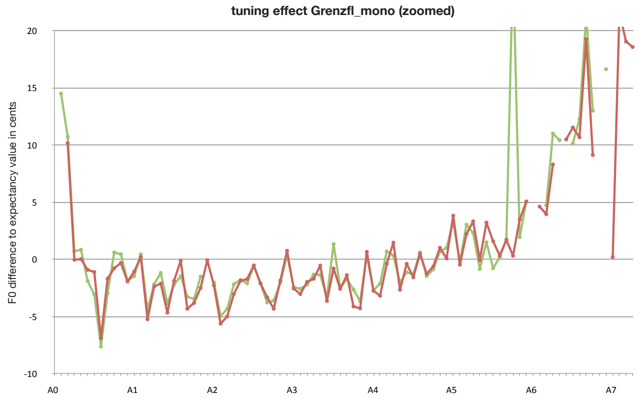


Fig. 12: Measured F0 deviations from reference values in cents for boundary mic: tuned (red) and pre-tuned (green).

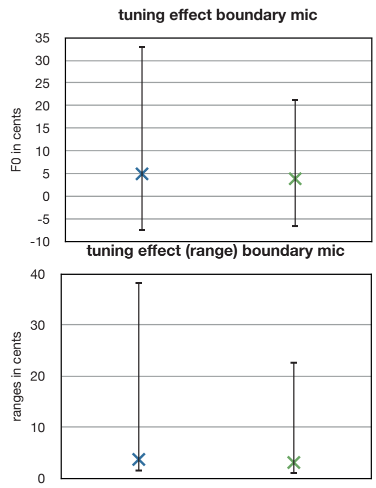


Fig. 13: Min, max, and mean absolute deviation (x) for boundary mic: pre-tuned (blue) and tuned (green).

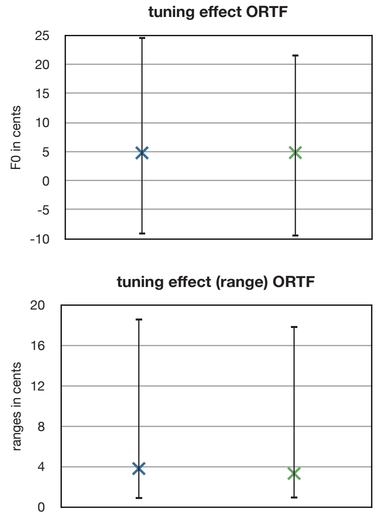


Fig. 14: Min, max, and mean absolute deviation (x) for boundary mic: pre-tuned (blue) and tuned (green).

Conclusion

Further research, enlarged sample base and refined statistical evaluation is necessary for citing general statements. This notwithstanding, the following preliminary results of our ongoing study are worth to be noted:

a) Statistically, only a slight tuning effect is present.

b) Interestingly, the recording technique does have an influence upon F0 measurements. This is possibly overlooked in comparable single setup studies.

c) Octave stretching and measuring noise seems to have a stronger effect on pitch than tuning alone.

d) Statement c) notwithstanding, absolute A4 reference pitch measured within 3 cents, what makes the previous statements a viable starting point for further research.

Notes

[1] Klouche, Timour, Teresa Samulewicz, and L. Jakob Bergner: Validation of computational tuning systems. In: Fortschritte der Akustik – DAGA 2012. Vol. I, 193–194. DEGA Berlin 2012.

[2] Klouche, Timour, Teresa Samulewicz, and L. Jakob Bergner: Measuring the accuracy of microtonal synthesizers: Pianoteq & Vogue. In: AIA-DAGA 2013, Proceedings of the International Conference on Acoustics, Merano. 279–282. DEGA Berlin 2013.
extended online version:
http://www.sim.spk-berlin.de/accuracy_of_microtonal_synthesizers_1344.html

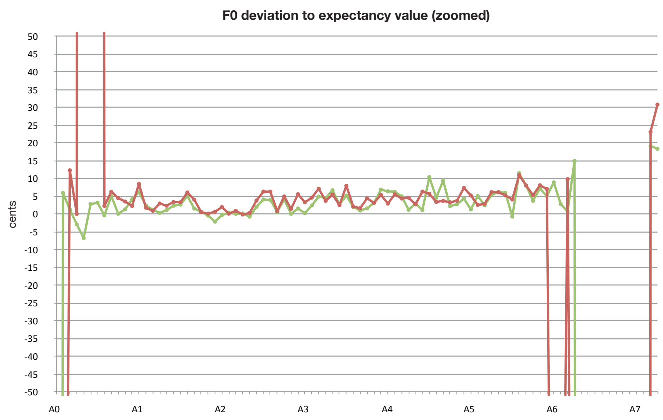
[3] Klouche, Timour: How microtonal is a well-tuned concert grand piano? In: Fortschritte der Akustik – DAGA 2014. Vol. I, 58-59. DEGA Berlin 2014.

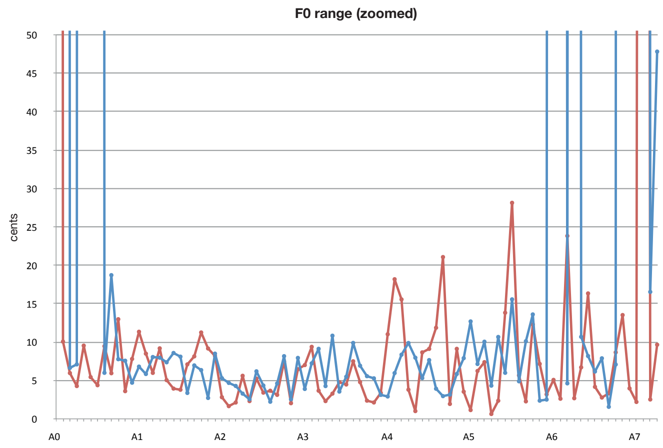
[4] http://www.sim.spk-berlin.de/

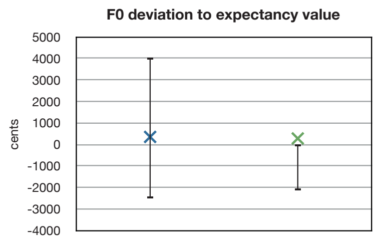
Annex

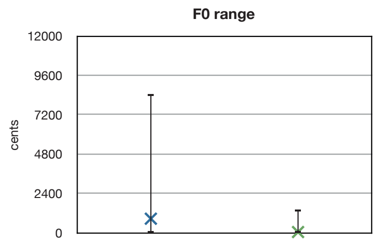
An additional sample measurement (no. 9 of the series), here raw data including all outliers is given for the interested reader. For analytical statements please consider the online version [4].

Pre-tuning F0 measurements









Post-tuning F0 measurements