Subjective Comparisons of “Virtual” Violins Obtained by Convolution

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Abstract

The subjective judgements on ancient violin are influenced by non acoustic phenomena, as the knowledge of the violin maker, the vision of the instruments and, for the performer, also the touch of the violin, the degree of conservation of the instrument, etc. Listening to “virtual” instruments let us to consider subjective evaluations in rapid sequences based only on acoustic events, without variation of other parameters, as performer playing, or kind of music, room acoustic, etc.
During this study, four “anechoic” music samples (Paganini, Bach, Mozart, Paganini), kindly played by Maestro Marco Fornaciari, were digitally recorded. He played on 3 different instruments in an anechoic chamber. Simultaneously the violin bridge-excitation and the acoustic response of the sound chest were digitally recorded on a two channels DAT , using a velocity transducer and a free field microphone.
Subjective pair tests were conducted, to determine the validity of the “virtual instrument” technique for comparison with recordings made with the actual different instruments. An arbitrary sequence of “real” acoustic signal pairs, convoluted pairs and control pairs (“truly equal” and “truly different” pairs) was created.
The results of the listening tests confirmed the excellent degree of similarity between the direct acoustic recording and convolution technique; furthermore the analysis of the two control groups validates the significativity of the test.
These results suggest that it will be possible to correlate subjective evaluations and physical characteristics of the instruments, by using the convolution technique.

1 Convolution by Frequency Domain Processing

Since some years specialised hardware to perform continuous delayed convolution exist [1], but they are still very expensive and don’t allow easily to digitally transfer the input and output signals on a PC. These devices are using Frequency Domain Processing with large blocks of data, resulting in a delay that is 3-4 times larger than the impulse response length. Time domain processing DSP boards, on the other hand, are capable of time domain

convolution with no delay, but are limited to a few thousands of filter taps (in the better cases).
In this work a software fast convolver (Aurora), running on a standard PC hardware, was employed. The Aurora system make use of a very different approach: both the input and output data files are stored on the hard disk in standard WAV format and, once convolution is performed, comparative tests can easily be conducted with just a “point and click” delay.
Convolution is performed through the well known “select-save” algorithm [2]: details and performances of the convolution software were already published in [3]. Now the program has been extended to longer impulse responses (up to 200000 taps) and speeded up a lot. This way it can handle the binaural reverberation simulation of large acoustic spaces [4].

2. Validation of the inverse filtering to recover the “anechoic” input signal

To validate the procedure of extracting the “anechoic” impulse signal from the microphone recordings taken in an anechoic chamber, a preliminary test was conducted.
4 “anechoic” input signals were recovered from microphone recordings of 4 different music pieces (2 of Paganini, one of Bach and the last of Mozart), with the technique already described in [5]; then they were convoluted with the impulse response of the same violin. These signals resulted almost indistinguishable from the original ones when listened in a normally reverberant space, whilst in headphone listening a little increase in the reverberation can be evidenced for the convoluted signals, for the reasons explained in [5]. In any case, the timbric perception was almost perfect, and this is the most important aspect for violins.

3. Subjective Test to Compare the Acoustic Quality of Violins

For a long time many peoples were studying the acoustic characterisation of musical instruments using conventional methods (i.e., by comparing the music played on different instruments); today, by using the novel convolution technique, it is possible to correlate the objective acoustic properties of violins with subjective evaluations without the need to collect dozens of performance recordings over different instruments.
To test the feasibility and robustness of the new technique, a large pair comparison test was conducted, with the aim to evaluate the subjective perceptibility of differences among different instruments.
Four different Instruments were employed for this test: the first is an ancient Violin (Klotz), kindly offered from the Cremona’s making school, the second is an other ancient Violin, (Calcanius), and the last violin is a Langhoff. At the end, a very different timbric Instrument, a viola, was utilised to create “really different” pairs.
Two “anechoic” samples were used for the test: a music piece of Paganini and one of Bach. The music pieces were kindly played by Maestro Marco Fornaciari.
The “anechoic” input samples were obtained by deconvolution of the impulse response of the Langhoff’s violin from the pressure signals directly recorded in anechoic chamber during the music playing, as already described in [5].
The “anechoic” input samples so obtained were convoluted with the measured impulse responses of the different instruments. Thus 3 pairs of convoluted samples were obtained. At the other hand, 3 pairs of “microphonic pieces” were added to the set of data, in which the presentation order was randomly shuffled. To obtain comparison data, two “control groups” each of 3 pairs of samples were mixed with the “true comparisons” set: 3 “really equal” pairs (obtained playing twice the same sample) and 3 “really different” pairs (obtained with convoluted pairs in which each violin is compared to the viola).

The same iteration was repeated for each kind of music: Paganini and Bach, in order to get 24 total pairs.
9 subjects were asked to listen to the 24 pairs, filling up for each pair the following questionnaire:

Pair no. .... Are the two violins A and B the same? yes π no π

If Your response is no, explain why:

	a lot (-2)	slightly (-1)	no difference (0)	slightly (+1)	a lot (+2)	
A is better	π	π	π	π	π	B is better
A has more pronounced bass	π	π	π	π	π	B has more pronounced bass
A has more pronounced treble	π	π	π	π	π	B has more pronounced treble
A is softer	π	π	π	π	π	B is softer

3.1 Subjective results

The following table summarises the results of the first question (percentage of "equality"):

Convoluted samples	Microphonic samples	Truly equal samples	Truly different samples
14.6 %	12.5 %	75 %	0 %

These percentages show that convoluted simulations have actually almost the same degree of dissimilarity as microphonic recording. But the truly equal and truly different samples are clearly recognised by the listeners.
Analysing the other 4 responses, the following three tables are obtained for the three violins studied, showing the average value and the standard deviation of each response:

Langhoff Violin

	Conv. samples	Microph. samples	Equal samples	Different samples
better	-0.69 ± 0.83	-0.28 ± 1.01	0.0 ± 0.71	0.37 ± 1.41
pronounced bass	-0.28 ± 0.81	-0.31± 0.98	0.0 ± 0.35	–0.56 ± 1.22
pronounced treble	-0.37 ± 1.01	0.0 ± 1.05	0.0 ± 0.50	1.44 ± 0.93
soft	-0.16 ± 1.18	-0.19 ± 1.11	0.06 ± 0.56	-0.75 ± 0.97

Klotz Violin

	Conv. samples	Microph. samples	Equal samples	Different samples
better	-0.16 ± 1.17	-0.03 ± 1.01	0.19 ± 0.39	0.75 ± 1.48
pronounced bass	0.34 ± 0.93	0.12 ± 1.25	-0.13 ± 0.33	-1.06 ± 0.97
pronounced treble	-0.19 ± 1.03	-0.09 ± 1.05	0.13 ± 0.48	1.25 ± 0.83
soft	0.03 ± 1.03	0.09 ± 1.06	-0.06 ± 0.43	-0.75 ± 1.20

Calcanius Violin

	Conv. samples	Microph. samples	Equal samples	Different samples
better	0.44 ± 1.05	0.72 ± 1.17	-0.13 ± 0.48	0.12 ± 1.05
pronounced bass	-0.03 ± 1.10	0.16 ± 1.05	-0.19 ± 0.53	-1.06 ± 0.97
pronounced treble	0.19 ± 0.93	0.47 ± 1.06	0.19 ± 0.53	1.25 ± 0.83
soft	0.16 ± 1.09	0.06 ± 1.17	-0.13 ± 0.60	-0.19 ± 1.18

It can be observed that the values of convoluted samples pairs are very near to those obtained from microphonic samples, as the differences are always lower than the standard deviations.

On the other hand, the control groups show very different responses, that approach almost perfectly zero for the truly equal pairs, and exhibit extreme values for the truly different pairs. This effect can be observed in a more evident way by looking at the graphs of fig. 1. The truly equal pairs always show a strong peak on the "0" (equality), while the truly different pairs show an evident trend toward an extreme of the scale. This is due to the fact that actually the viola is a very bad instrument compared to three violins (question n. 1), it has more pronounced bass (question 2), it does not have treble (question 3), and is certainly softer than the violins (question 4).

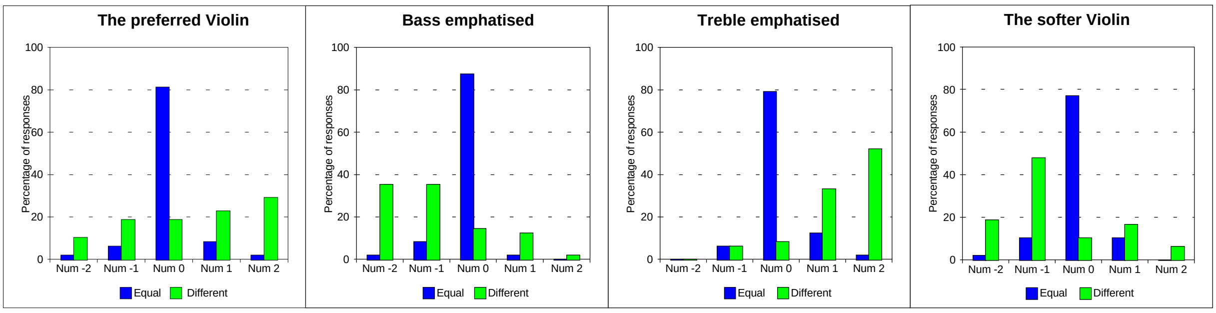

Fig. 1 - Distribution histograms for "truly equal" and "truly different" pairs

From the analysis of the control groups it can be concluded that the subjective test is reliable, and that the subjects were able to correctly identify acoustically evident differences or similarities. The graphs of fig. 2 and 3 compare the response obtained with the new "virtual instrument" technique with the traditional acoustic recordings of different violins. If the new technique is behaving correctly, the graphs of fig. 2 should be equal to those of fig. 3

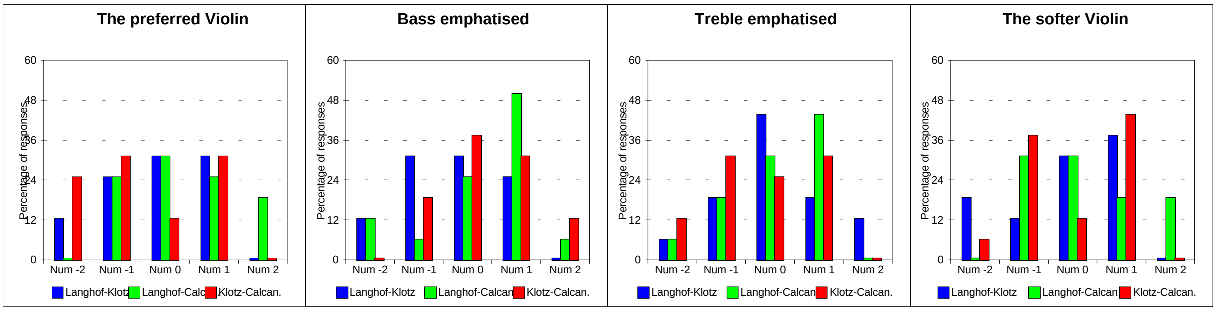

Fig. 2 - Distribution histograms of the four questions: microphonic pairs

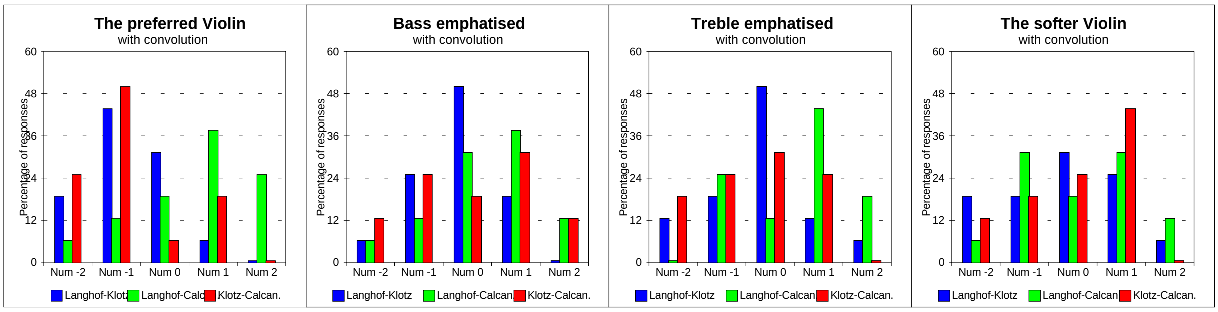

Fig. 3 - Distribution histograms of the four questions: convoluted pairs

3.2 Discussion of the results

Although a certain degree of similarity can be seen, there are still some differences between the graphs in fig. 2 and the corresponding in fig. 3, differences which however are not significative compared to the wide spread in the subjective responses. The general problem of this subjective test is exactly this: the spread is so large that actually no significative difference is found between the responses relative to the three violins, and this happens almost at the same degree both with convoluted pairs and with the microphonic pairs. This contrasts with the results of the control groups, and also with those of the first question, where it was clear that the subjects correctly identify as different these three instruments: they realise that the instrument is changed, but then they are not able to determine with precision what is changed, and even which of the two instrument is better! Probably the test has to be repeated with a larger panel of trained, sharp-eared musicians, in place of a little group of students at the Bologna’s Engineering Faculty, as this was the case.

In any way these results validate the novel technique proposed: the convoluted pairs give almost the same results as the direct microphone recordings, requiring however a smaller effort, as a simple and fast measurement is taken on each violin, without the need of a musician performing various samples in an anechoic chamber. In this way, a large number of violins can be compared.

The convolution time required to convolute the “anechoic” input signals with the impulse response of each violin is also very short (on a 486 DX2-66 PC it is about 3 times the sample length). So comparative tests can be conducted with many different music pieces, provided that suitable “anechoic” input signals are prepared just once.

4. Conclusions

The results of the subjective experiment conducted show that the new convolution technique make it possible to create “virtual violins”, that are digital filters capable of reconstructing almost perfectly the time and frequency response of a real instrument.

The advantages of the new technique are many: a simple, fast objective measurement is first taken on each instrument, from which objective quality parameters can be extracted. Then music performances over the instrument are simulated by convolution, without the need that a violinist plays the instrument; furthermore in this way any variation in the performance is avoided, as exactly the same input signal is applied to all the instruments, whilst it is known that the violinist always modifies its execution depending on acoustical and non-acoustical characteristics of the instrument.

For these reasons it is expected that, employing the convolution technique, a better correlation between objective acoustical parameters and subjective evaluations will be found.

The prosecution of the research will be a large objective measurement campaign on dozens of instruments, followed by a subjective listening test with a selected panel of musicians and violin experts. Furthermore the possibility to make numerical modifications to the measured impulse responses enables the subjective evaluation of non-existing instruments, which is important for the aesthetic research.

5 Acknowledgements

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6 References

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