Time Relations between Violin Tone Harmonics in Relation to Playing Techniques

Petr Volný, Jan Štěpánek, Václav Syrový

Music Faculty, Academy of Performing Arts in Prague,
Malostranské nám. 13, 118 00 Praha 1, CZECH REPUBLIC,
E-mail: VOLNY, STEPANEK@H.AMU.CZ

Summary: Particular violin tones were played by a professional violin player in an anechoic room. The open tones from the whole violin range, played non-vibrato using selected bowing techniques (*sul tasto, naturale, sul ponticello*) and dynamics of playing (*piano, mezzoforte, forte*) were recorded. The analysis based on the Hilbert Transform of filtered signals was used to compute the time envelope of amplitudes of separated harmonics from the SPL-recordings of the tones. In the next step, the time characteristics of the time envelopes of the whole tone and its harmonics were calculated. Attack and decay gradients and their dependence on playing techniques and dynamics were studied. The results successfully correlate with the physical conditions of bowed violin tones.

INTRODUCTION

The results published in this paper are part of ongoing research, the final result of which will be a taxonomy of signals of musical instruments used in a symphonic orchestra. Published here are the results of analysis of signals produced by a violin played in an anechoic room. The method of recording is described in (1). This paper deals with time properties of musical signals.

The aim of this work is to automatize the evaluation of envelope parameters of musical signals recorded digitally into a personal computer.

METHOD

The temporal characteristics of musical signals are mostly based on their time envelope evaluation. The way to find envelopes of time-courses in our work is their separation into harmonic components and computation envelopes of harmonics using the Hilbert Transform.

As written in (2), the **Hilbert Transform** of a signal *x(t)* filtered by the filter with impulse response *h(t)* is defined by

$$\tilde{y}(t) = \int_{-\infty}^{\infty} h(u) \frac{x(u)}{\pi(t-u)} du$$

To filter the signal of the musical instrument, the IIR Butterworth **bandpass filter** type (order n=3) with constant bandwidth (B=10 Hz) was used. The center frequency for the signal filtering was obtained by taking the frequencies of harmonics in Power Spectral Density of the signal, computed by the Fast Fourier Transform. The envelope for the filtered signal was computed as

$$A(t) = \sqrt{y^2(t) + \tilde{y}^2(t)}$$

where $y(t)$ is the filtered signal and $\tilde{y}(t)$ is the Hilbert Transform of the filtered signal.

The next step was to specify the criteria to obtain the attack and decay time respectively of the time envelope. The definitions presented in the literature (3) are useful only for special cases of musical signals for two reasons. First, most of them have an inconstant level in the **steady state** (referred to as the quasistationary state). This fact has a significant influence in establishing the end of **attack,** and also the beginning of **decay,** events. And second, the increase of the envelope during the attack transient is often a non-monotonous function with more local maximums. To create a more simple course, a **progressive average** (PA) for the envelope was computed

$$\overline{A}_n = \frac{\sum_{k=1}^{n} A_k}{n} \qquad ;n=1\ldots\infty$$

A progressive average allows us to specify a new criteria for the determination of start and end times of the steady state of the harmonic, as shown in FIGURE 1.

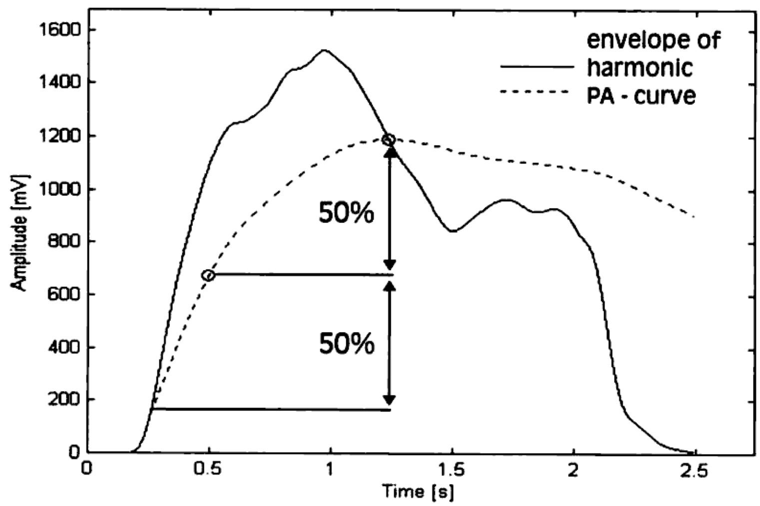

FIGURE 1. Time envelope of the violin tone fundamental and its progressive average (PA) curve, including the points for derivation of starting and ending times of the steady state (tone A4, naturale, mezzoforte).

The first average $\overline{A}_1$ was computed from the 10% level of the envelope's maximum (to avoid noise influence). The time at the 50% level of the first maximum of the PA, and the time of the last maximum of this curve, indicate the start and end of the steady state respectively.

The starting time of **attack** and ending time of **decay** are calculated using the linear extrapolation from the 10% and 5% levels of the envelope. The **attack** and **decay gradients** of the envelope, and their dependence on playing techniques and dynamics, can then be observed.

RESULTS

All open strings (G3, D4, A4, E5) were played using the three down-bowing techniques (**sul tasto, naturale, sul ponticello**) with three dynamics of playing (**piano, mezzoforte, forte**). Each tone was played three times. Altogether, 108 individual tones were recorded. The instrument used was a Francois Gand, Paris 1825. Digitalized signals were evaluated in the MATLAB 5.2, using our own special tool for signal envelope computation. The attack and decay gradients' results were imported into the STATISTICA 5.0 and sorted in it. Note that when using a digital filter a time delay is automatically included in the signal to be analyzed. When a relative comparison of attack and decay characteristics between signals is needed this influence is compensated. The effects of dynamics on playing for each bowing technique were plotted in line graphs. Two examples of this evaluated data visualization are shown in FIGURE 2 and FIGURE 3.

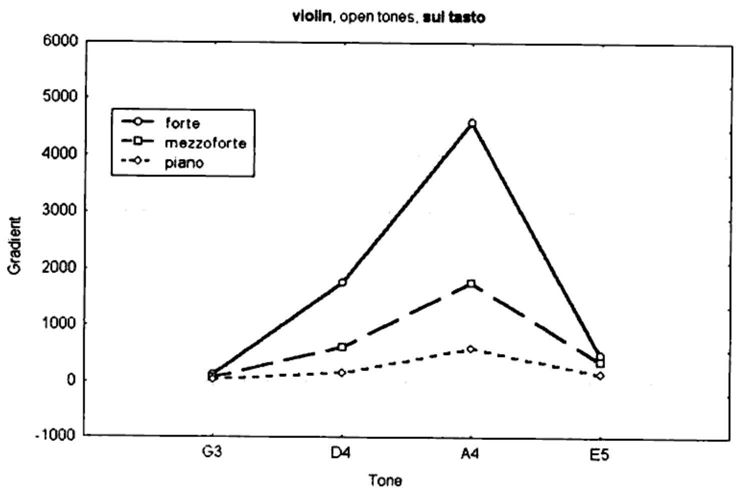

FIGURE 2. Attack gradients of envelope of violin's fundamental and their dependence on dynamics of playing.

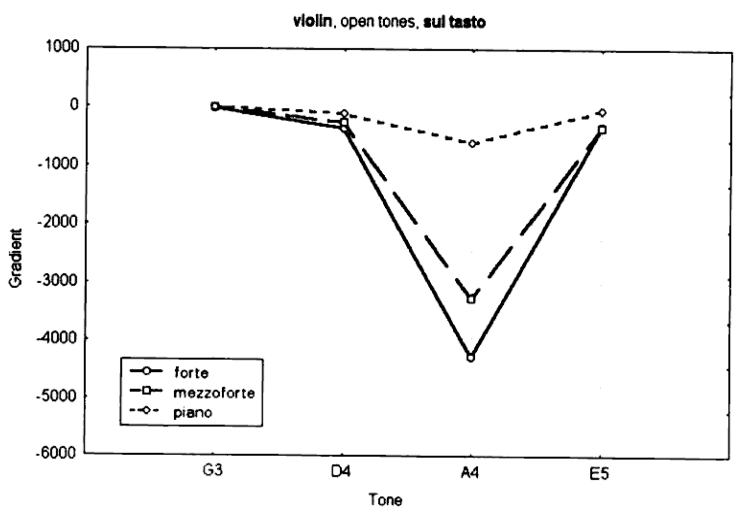

FIGURE 3. Decay gradients of envelope of violin's fundamental and their dependence on dynamics of playing.

DISCUSSION

After visualizing the data some typical trends in dependences can be observed:

With an increase in dynamics the gradients increase too (both for attack and decay). The attack gradients without exception rise more steeply than the decay ones. This means that the harmonics have shorter attack times than decay times -- and this fact is independent of dynamics and playing techniques.

The influence of playing techniques can be described in the same way: as the strings are bowed more closely to the bridge (**sul ponticello**), so the gradients increase, and vice versa. In a few exceptional cases of some played tones, the gradients of louder dynamics were smaller.

An interesting observation is the gradients' dependence on the strings played: in all combinations of dynamics and playing techniques the string A increases in its gradients more rapidly than the other ones. And in contrast with the A string, the string G changes its attack and decay gradients minimally with respect to dynamic changes.

ACKNOWLEDGMENTS

This investigation was supported by the Ministry of Education and Youth (Project No. VS 96031). The violin was played by J. Tomášek, Professor of the Music Faculty of the Academy of Performing Arts (HAMU) in Prague.

REFERENCES

(1) OTČENÁŠEK, Z., SYROVÝ, V., "Directivity of Violin Radiation", in *this proceedings.*

(2) BENDAT, J.,"The Hilbert Transform and Applications to Correlation Measurements, *Brüel & Kjaer,* Naerum, Denmark, 1982.

(3) LUCE, D., CLARK, M. *Journal of the Acoustical Society of America* **42**, pp. 1232-1243 (1967).