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OPENING TRANSIENTS AND THE QUALITY OF CLASSIC GUITARS

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Analysis of the correlation between opening transients of guitar sounds and the guitar quality as determined by the subjective assessment by music experts is presented.

1. Introduction

Earlier attempts, carried out in various laboratories, to find out which of the easily measurable physical characteristics of guitars could well represent their quality were not very successful. These attempts pertained mostly to the frequency response of guitar resonators [1-3].

As a rule, the frequency response of a guitar resonator is rather complex and cannot be approximated by simple functions. Therefore for a pragmatic type of analysis only the most pronounced resonances or the general features of the integrated frequency responses are usually taken into account. To add to the complexity of the problem, the frequency responses depend significantly on the type of excitation of the resonators, i.e. on the nature of the signal, the point of application of the transmitting and receiving transducers or the location and distance of the microphone, if used. In addition, it is well known that the frequency response depends on the brand of the strings and their tension.

Although various experiments in our laboratory produced a vast amount of data, the analysis often showed only slight correlations between easily distinguishable resonances in the frequency response and the subjective quality ranking.

Further work was directed to the measurement of the frequency spectrum of guitar sounds. For some purely technical reasons, in these experiments the amplitudes of partials of the sounds analysed, were recorded on the spectrum charts at the time instants always corresponding to the maximum of

signal amplitude. Unfortunately the sound spectra recorded in such a way were very similar for the worst and the best guitars tested, and could hardly be used for a comparison of instrument quality. The natural solution in such a situation would be to measure the running spectrum of the subsequent guitar sounds. This method, however, appeared to be very troublesome.

The differences in the subjective quality assessment pertained particularly to the initial transient of the sounds. Sounds characterized by a very rapid initial transient were often defined as "hard", "flat" or "noisy" and were scored low. On the contrary, high scores were mainly assigned to sounds rising slowly in loudness and usually defined as "soft" or "pleasant". Thus the next step in the research programme was the measurement of the opening transient (attack or onset) times of the subsequent sounds of various guitars, and a comparison of the results with the subjective quality assessment. This part of the programme is covered briefly in the present report.

2. The examined instruments

The experiments were performed using thirteen classic guitars well differentiated as regards their quality. It must be emphasized, however, that these instruments ranged from quite poor inexpensive student instruments to average master-class hand-made guitars. No instruments of a very superior quality were included in the tests. All these instruments were tuned to A4 = 440 Hz prior to the quality assessment by expert guitar players and sound temporal analysis. All sounds up to the fourth position were examined, except for the E4 string on which the fifth position was also used. In such a manner, the onset times were determined for all the chromatic scale sounds from E1 to A4, for each guitar tested.

3. Subjective quality assessment

Three well recognized professional guitar players who were experienced in similar tests served as experts in the quality assessment. The assessment sessions were distributed over six months and lasted from 30 min to 1,5 h each, depending on the spare time of the musicians. Instruments were compared in pairs by playing single sounds or chords (but not tunes) on each of the two instruments, using sounds from E2 to A4. The expert's final task in each comparison was to decide which of the two guitars sounded better. The time limit for the comparison of one pair was approximately 30 min. Usually one or two, but never more than three judgements were made in one session. The tests were carried out in a typical classroom.

4. Onset time measurements

The experimental arrangement used for the tests was very simple. The strings in all tested instruments were activated using a small piece of plastic material with a very thin metal layer thickness $0{,}3 \cdot 10^{-2}$cm covering one side of the plastic. Plastic strings were used. Bass strings had usual metallic winding, the remaining strings obtained a short, very thin, copper wire winding. Both the strings and the metal layer on the piece of plastic used for string activation were connected to the electronic circuit, which, at the instant of opening the circuit, produced an electric pulse of about 10^{-5} sec duration at its output. This pulse was fed to the synchroscope and used to trigger the time base.

The sound signal was picked up using a Brüel & Kjaer 4331 condenser microphone located 50 cm from the top plate in the direction approximately normal to its center. This signal was fed via a Brüel & Kjaer 2604 amplifier to the synchroscope and photographed. The onset times were determined as the time between the detectable beginning of the signal and the moment at which the amplitude of the signal reached its maximum. In cases where this procedure could not have been used (i.e. for sounds which increased in loudness firstly rather rapidly and then only slowly) the time to reach a value of 90 % of the maximum amplitude value was taken as representative.

Preliminary measurements showed that in low quality instruments the opening transient envelope usually depended strongly on the force applied to sound the string, particularly at low sound intensity levels. For higher levels this dependence was determined to be insignificant and could have been neglected. For this reason all the onset time measurements and the subjective quality assessment were carried out at loudness levels proximal to mezzo-forte forte.

5. The results

The results are presented in Figs. 1, 2 and 3 which show the correlation between the onset times and quality assessment in the 13 instruments investigated. In Fig. 1 the distribution of all of the 30 onset time values for each instrument is shown, the histograms being ordered according to the quality assessment of the instrument: from 1 (the worst guitar) to 13 (the best one). The median values and interquartiles of all the 13 distributions are shown in Fig. 2. To evaluate the relative value of the dispersion of the results the ratio $2Q/M$ was computed for each distribution and the results are presented in Fig. 3. The following additional observations were made:

Sounds with longer onset times had generally a shorter decay and were often described as "pleasant" and "soft".

Sounds with shorter onset times had generally a longer decay and were often described as "flat", "hard" and "less tonal".

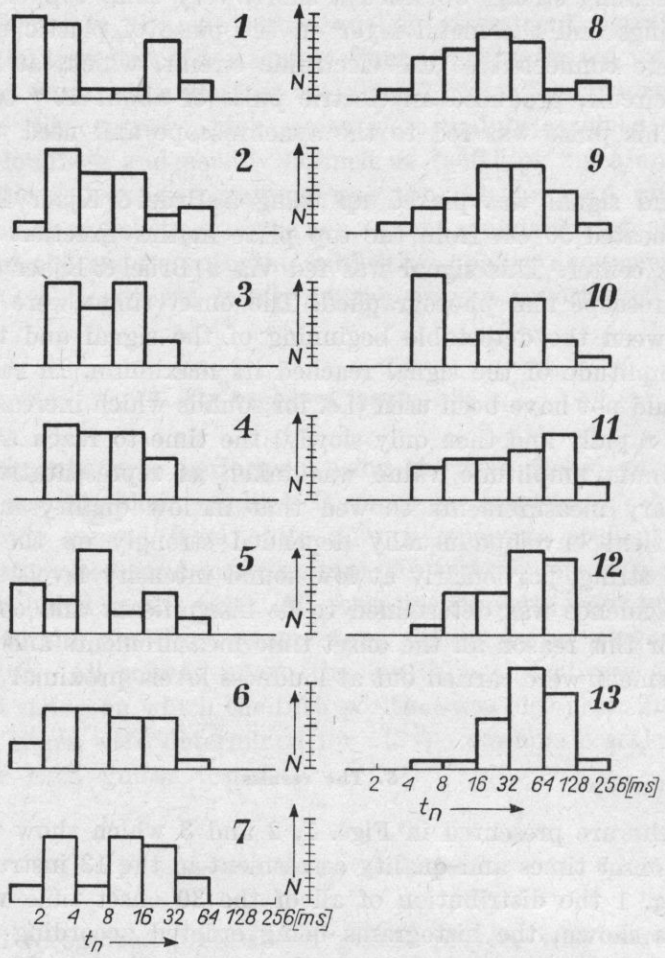

Fig. 1. Onset time histograms for 13 guitars of various quality, ranging from very low quality (1) to very high quality (13)

t_n — onset time, N — number of sounds within each t_n class

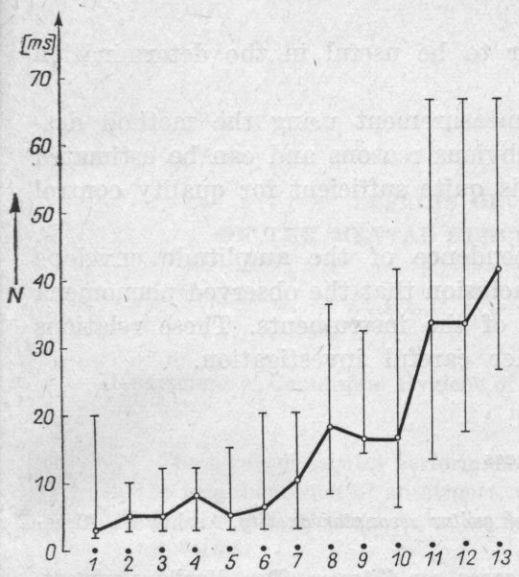

Fig. 2. Median values and interquartiles of the onset times of sounds for 13 guitars ranged as in Fig. 1

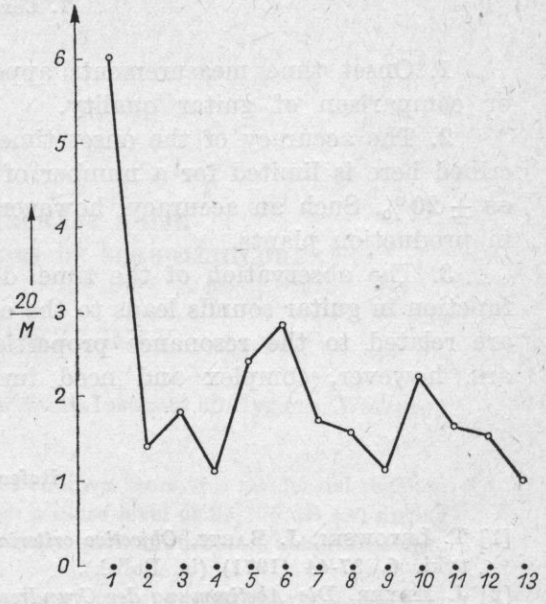

Fig. 3. Ratio of interquartile ranges and medians of the onset times of 13 guitars ranged as in Fig. 1

6. Discussion

The results presented in Figs. 1 and 2 show a rather pronounced correlation between the subjective quality scores and the onset times. The presentation of the results in Fig. 3 shows also that the higher scored instruments show a smaller relative dispersion of the values of the onset times. For example the instrument scored 1 (lowest subjective quality) had the longest onset time — 40 ms; and the shortest — 1 ms (ratio 40 : 1) while the best scored instrument (13) had the longest onset time of 132 ms whereas its shortest time was only 16,5 ms (ratio 8 : 1). However it must be emphasized that in the instrument scored 13 only D3 sharp had such a short onset time, the remainder were all above 30 ms whereas in the instrument scored 1 most of the sounds over the whole range of the scale, tested from E2 — E4, had onset times ranging from 1 to 3 ms.

It should be also emphasized that in revealing the relations between the amplitude envelope form and the quality scores a large amount of information is ignored. The shape of the envelope changed dramatically and it is believed that apart from the onset time, the shape of the envelope may have influenced the quality scoring.

7. Conclusion

1. Onset time measurements appear to be useful in the determination or comparison of guitar quality.

2. The accuracy of the onset time measurement using the method described here is limited for a number of obvious reasons and can be estimated as $\pm 20\%$. Such an accuracy, however, is quite sufficient for quality control in production plants.

3. The observation of the time dependence of the amplitude envelope function in guitar sounds leads to the conclusion that the observed phenomena are related to the resonance properties of the instruments. These relations are, however, complex and need further careful investigation.

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