Vibration and Sound of the Indian *Tabla*

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Introduction

The *tabla* pair is a fundamental musical instrument of the traditional music of North India. It consists of two drums, the bigger *bayan* which is played by the left hand and the smaller *tabla* which is played by the right hand. The latter was investigated in terms of mechanical vibration and musical sound, including a psychoacoustically-based approach.

Figure 1: *Tabla* of Parvinder Bharat.

Fig. 1 shows a photograph of the instrument. The head is composed of different layers [1], in particular a central "black patch" on the main skin, and can be modelled as an inhomogeneous membrane [2]. Due to the non-uniform mass distribution and the structure-fluid interaction, the intervals of the partial tones do not obey a Bessel law, but are near-harmonic [2]. The vibration of the head was experimentally investigated by Laser Doppler vibrometry; the results were presented and extensively discussed in [3]. In the following investigation, the vibration modes are related to the acoustic components of two standard *tabla* strokes, *tun* and *na*.

FFT analysis of two tonal *tabla* sounds

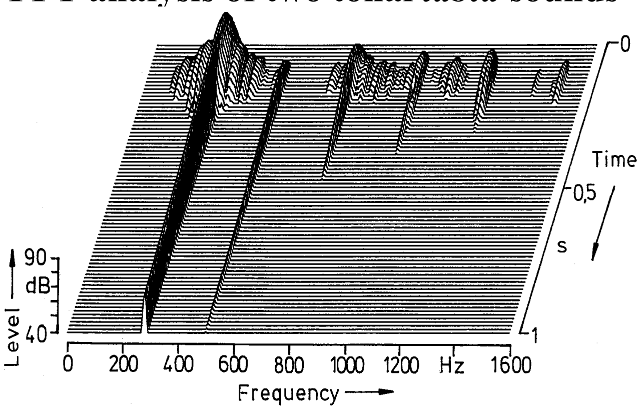

Figure 2: *Tabla* sound *tun.*

The sounds, which the professional Anglo-Indian *tabla* artist Parvinder Bharat played on his instrument, were recorded on DAT and analysed by an Ono Sokki CF 5210 FFT analyser. The sound level (40 ... 90 dB) is displayed versus frequency (0 ... 1,6 kHz) as a function of time (0 ... 1 s) in Figs. 2 and 3.

To generate *tun*, the player plays the *tabla* "open" and strikes the head by the index finger close to the central black patch. The 3D representation of Fig. 2 shows that a strong component at 272 Hz with long sustain dominates the sound signal. The remaining components are minor in magnitude and shorter in temporal duration. A tone of low pitch and long duration is perceived.

For generating the sound *na*, the player "fingers" the tabla head. In contrast to the "open" *tun*, he holds the ring finger softly against the head and strikes it by the index finger close to the rim. As Fig. 3 reveals, the acoustic spectrum proves to be rather different. The first component is totally lacking. The next one is comparably low in amplitude as in Fig. 2. The third component at 744 Hz has the greatest level. A tone of sharp pitch and short duration is perceived.

Psychoacoustically-based analysis of *tun* and *na*

Although these results are significant, there could be more suitable analysis tools than the purely physically motivated FFT. The software VIPER by Cortex accounts for some fundamental properties of human audition. It offers several stages of aurally-adequate signal analysis. The auditory spectrogram (first stage) is based on a critical band (Bark-scale [4]) analysis. Tonal components can be extracted as frequency contours (second stage) and frequency tracks (third stage) including the influence of spectral masking [4, 5]. This most advanced stage of the aurally-adequate sound analysis is shown in Figs. 4 and 5. The tracks of the tonal components are plotted on a Bark scale (left ordinate: 0 ... 16 Bark) as well as a frequency scale (right ordinate: about 0.020 ... 3 kHz) as a function of time (abscissa: 0 ... 1 s). The level is coded in colours (light grey: ≤30 dB ... blue .. green ... yellow ... red: <80 dB). The psychoacoustically motivated

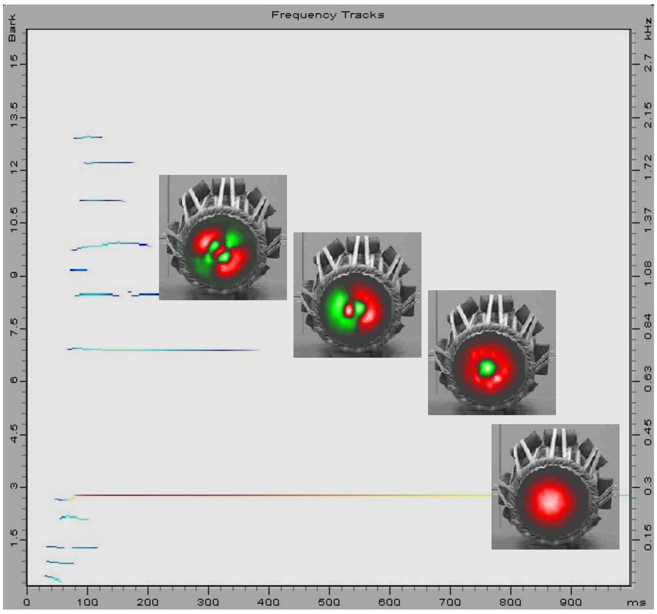

Figure 4: Frequency tracks and vibration patterns of *tun*.

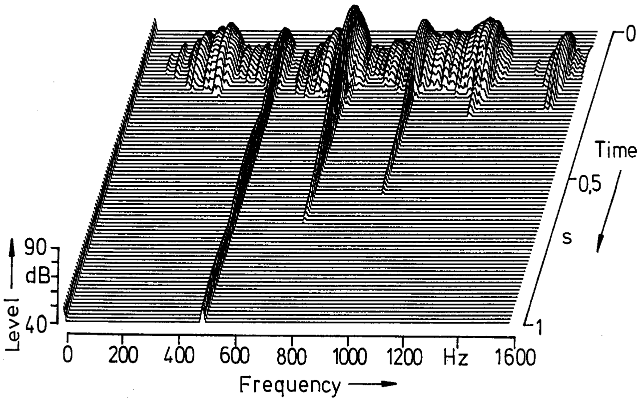

Figure 3: *Tabla* sound *na*.

representation of the two *tabla* sounds is displayed immediately beside the corresponding objective result of the FFT analysis. For better comparison, it should be rotated by -90^0.

In Figs. 4 and 5 the audible partial tones are represented as coloured lines of different lengths. Remarkably, the second component of *tun* (Fig. 4) at about 500 Hz proves to be irrelevant due to spectral masking. In contrast to the FFT spectrogram of Fig. 2 it is not displayed as a partial tone in the "masked" frequency tracks of Fig. 4.

Discussion

Since the knowledge of the vibration patterns of the head is the key to the physical understanding of the striking and fingering techniques, the results of the Laser measurements are inserted in the frequency tracks diagrams. Green and red represent different signs, light areas mean antinodes and dark lines mark vibration nodes.

Tabla sound *tun*

The stroke *tun* sounds low and long-sustaining. Because the head is not loaded by the fingers, in principle all vibration modes are evoked. From the Figs. 2 and 4 it follows that the player has chosen the striking point such that the first axi-symmetric mode (0 -1: 0 nodal diameter, 1 nodal circle at the rim) and the corresponding partial tone of 272 Hz is strongly excited. The second acoustic component of about 500 Hz is related to the anti-symmetric 1-1 mode, which is so weak in amplitude that it is aurally irrelevant. Further partial tones at 748 Hz (0-2 mode), 984 Hz (1-2 mode) and 1248 Hz (2-2 mode) are smaller in magnitude and shorter in sustain. Forming a near-harmonic pattern, they may influence the timbre. In total, the subjective duration and the musical pitch are determined by the first (0 -1 mode) partial tone.

Tabla sound *na*

The stroke *na* is perceived as a bell-like sound of sharp pitch. The player achieves this by the particular fingering of the head and the apt point of excitation. The ring finger, which is in loose contact with the skin, enforces a nodal line at the contact region. It can be observed from Figs. 3 and 5 that the first component is suppressed. Obviously, the finger resting on the skin damps the axi-symmetric 0 -1 mode. Only anti-symmetric vibrations with at least one nodal diameter evolve. The partial tone of 492 Hz, generated by the 1-1 mode, sustains long but has only a low level. The next component at 744 Hz is strongly evoked. The corresponding vibration is a combination of the 2-1 and 0-2 modes that practically have the same frequencies [1, 3]. The resulting partial tone decays quickly but starts with such a high level

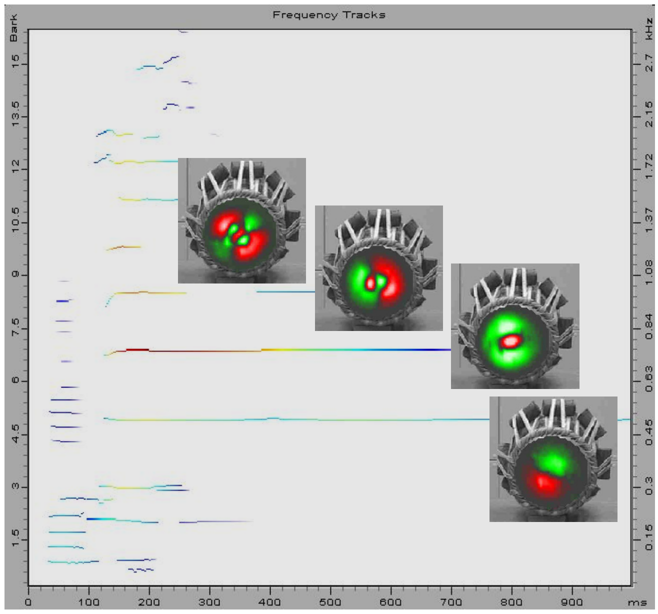

Figure 5: Frequency tracks and vibration patterns of *na*.

that it most probably will determine the musical pitch of *na*. While the 1-2 vibration (partial tone at about 1 kHz) is again a normal mode, the mode generating the partial tone with frequency 1230 Hz seems to be a combination which includes among others the 2-2 mode [1, 3].

Final Remark

To understand what happens if a membranophone is played, the vibration of the head as well as the components of the acoustic signal must be known. Laser velocimetry proves as a suitable tool for non-contact measurement of the vibration. For investigating the sound, both "objective" FFT and a "subjective" aurally related analysis approach were used.

Apart from the complicated rhythmic structures, which were not treated here, the art of the *tabla* player is to selectively excite and suppress mechanical vibrations by sophisticated striking and fingering techniques. The two basic tonal strokes, *tun* and *na*, which evoke different pitch perceptions, are selected as significant examples.

Since the purpose of a musical instrument is to generate sound of certain aural properties, it is a self-evident idea to analyse its acoustic signal according to the properties of the ear. To accomplish this, the analysis should include the fundamental psychoacoustic effects. The software used should account for the critical band resolution of human audition [4] and should be able to extract partial tones [5]. Last but not least it proves as extremely helpful to reduce the physical information to the aurally-relevant content of the signal by considering spectral masking [4, 5]. An apt psychoacoustically-based analysis, especially simulating the masking effect, proves to be a powerful tool for investigating musical sounds.

Literature

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