Simulation of Natural Sound Sources

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Introduction

Many applications like real-time spatial sound rendering for virtual environments or room-acoustical simulations [1] gain in naturalness if the simulated sources are able to rotate and the listener has the opportunity to move or rotate himself. In this case not only the spatial information is required but also the directivity of a sound source needs to be considered for a close to reality reproduction of an acoustical scenario. Especially for natural instruments the directivity determination in the complete sphere is not as easy as for electro-acoustical sources. The excitation variability by a human player eliminates the possibility of sequential measurements of different angles. In this paper the measurements of various instruments are introduced. The influence of averaging the directivity information extracted from different single tones of a scale is analyzed and compared to the directivity extracted from a short piece of music.

Measurement

During this investigation the following instruments were measured:

Piccolo-trumpet, Trumpet, Flugelhorn, Trombone, Violin, Viola, Clarinet, Oboe and Transverse Flute.

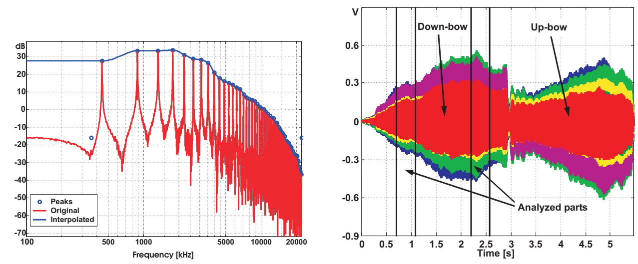
For each instrument the following takes were recorded:

- Single tones covering the complete scale of the instrument in different levels.
- A short piece of music with a representative pitch range.

All instruments were recorded using 24 microphones (Sennheiser KE4). The instrument was placed in the center of a sphere with a radius of 1.56m. Eight microphones were paced on the azimuth plane of 0° and 45° respectively, one microphone was located was placed at each pole (above and below the instrument) and the remaining six microphones were located at the −45° azimuth plane. All recorded tracks were analyzed using measurement software Monkey Forest to ensure a correct time alignment of the 24 channels. The focus in this paper is to generate directivity data valid for the complete pitch range of an instrument. To outline different aspects and their limitations only two instruments will be discussed as example for directional radiating instruments like a trumpet and rather undirectional instruments like a violin. Furthermore all recordings were done for different levels. The level was increased in approximately 5 dB steps to cover the whole dynamic range of the specific instrument. Differences can also be obtained but will not be discussed. More information about the influence of the level can be found in [2].

Analysis of single tones

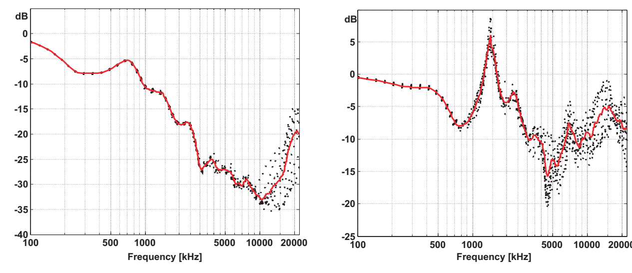
For each single tone a piece of 16384 samples (371 ms) with constant amplitude is selected ensuring the exclusion of onset and decay. After the transformation into the frequency domain the frequency resolution is 2.7 Hz. Figure 1(a) shows the spectrum of the standard pitch with a level of 90 dB at 2 m. All these frequency plots contain the fundamental frequency (in this case 440 Hz) and the harmonics with different characteristics dependent on the instrument the level and the direction. To generate directivity data all frequency plots will be interpolated using the peaks as sampling points (see figure 1(a)).



(a) (b)

Figure 1: (a) Interpolation of the frequency response. (b) Recorded single tone of a violin (fis' = 370 Hz)

Analysis interval



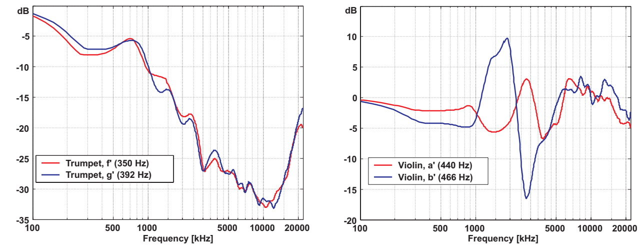
(a) (b)

Figure 2: Influence of the selected and analyzed part of a single tone

To evaluate the influence of different areas of analysis several parts (16384 samples / 371 ms length) of the signal shown exemplarily for a violin in figure 1(b) are selected and compared. Figure 2 depicts the differences for one tone of the trumpet (a) and violin (b) for one single direction of azimuth 90° and elevation 0°. The red curves illustrate the averaging of all different areas of analysis described by the dotted lines. It can be seen that the curves of the trumpet fit almost up to 5 kHz the violin shows good conformity up to 3 kHz.

Pitch

Accordind to this a directivity which is valid for the complete frequency range of a specific instrument it is required to average the directivity information of all possible tones. Related to that it is important to know whether the played tone of the instrument affects the directivity. For this reason several interpolated frequency spectra of different tones were compared. Figure 3(a) shows that two tones played on a trumped (red solid curve: f' = 350 Hz, blue curve: g' = 392 Hz) with a distance in pitch of 42 Hz cause not exact the same directivity. Even a stronger influence can be noticed for the violin (figure 3(a) red curve: a' = 440 Hz, blue curve: b' = 466 Hz. A difference in pitch of only 26 Hz causes a reversion of the directivity characteristic between 1 kHz and 4 kHz.



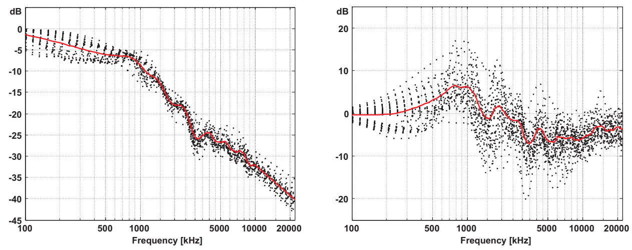
(a) (b)

Figure 3: Influence of pitch on the directivity. Direction: azimuth 90°, elevation 0°

Figure 4 shows the sets of curves related to 32 different tones each for trumpet (a) and violin (b). The range of tones is from e = 165 Hz to b" 932 Hz. For the trumpet it is possible to generate a general directivity which is valid for all tones. This is similar for most of the instruments of the same "family" as e.g. piccolo-trumpet, flugelhorn, trombone etc.. The set of curves related to the 32 tones (g = 196 Hz to d"' = 1175 Hz) of a violin shows a distinctive deviation to the average curve. For a general valid directivity the inclusion of all possible tones of the instrument is important. Due to the high deviation an averaged directivity causes a loss of accuracy.

Analysis of a phrase

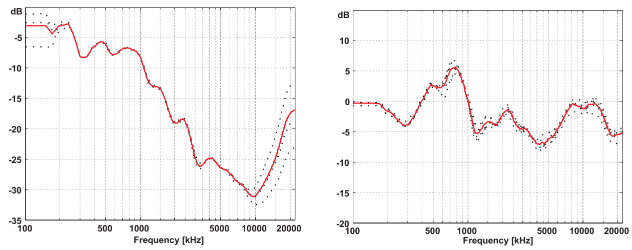
A different method to generate a directivity is not to use an averaging over the scale of single tones but to use a short piece of music with a representative pitch range. For this reason several parts of a recorded song were analyzed. These parts with a length of 11.9 s were transformed into the frequency domain and smoothed using a 1/3 octave window. Comparing different areas for the generation of the directivity data shows that the influence is rather low. The plots in figure 5(a) (trumpet) show that all areas produce the same frequency spectrum



(a) (b)

Figure 4: Averaging (red solid) of 32 different tones (black dotted). Direction: azimuth 90°, elevation 0°

up to 8 kHz. Except for some variations of the minimum and maximum peaks all curves fit for the whole frequency range. The differences are almost below 2 dB.



(a) (b)

Figure 5: Differences of the directivity according to the analyzed phrase.

Summary

This study shows that it is for some instruments a complex task generating a directivity which is valid over the whole frequency range. For a lifelike simulation of natural instruments it is required to change the directivity according to the played tone [3]. Another possibility is to split the directivity into more sectors and provide a separate recording for each sector. This moves the pitch related information into the recorded material, but makes it possible to connect the directivity to typical room-acoustical simulation techniques. In real time applications where a split of the directivity is not possible due to rising processing requirements the generation of the directivity from a short piece of music corresponding to paragraph seems to be an appropriate method.

References

[1] Schröder, D., Lentz,T., Echtzeit-Implementierung des Spiegelschallquellenverfahrens, DAGA, 2005.

[2] Meyer, J., Akustik und Musikalische Aufführungspraxis. Verlag Erwin Brochinsky, 4. Aufl. (1999)

[3] Otondo, F., Rindel, J.H., Caussé R., Misdariis O., De la Cuadra P., Directivity of musical instruments in a real performance situation, Proc. International Symposium on Musical Acoustics, Mexico city, Mexico, pp. 312-318, 2002