Directivity of musical instruments in a real performance situation

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Measurements of the directivity of musical instruments are presented in the context of a new directivity representation of sources for auralizations. Three instruments have been recorded over the whole compass simultaneously in both horizontal and vertical planes with a multi-microphone array. Results are analyzed focusing on the differences between the directivity of particular tones and the averaged directivity over the whole compass. The consequences of these variations in a real performance situation in a room are looked into using computer room simulations. Further developments will consider room auralizations using different representations for the directivities of musical instruments.

I. INTRODUCTION

The directivity of musical instruments has been studied by several authors[1-3], Jürgen Meyer being probably the one who has contributed with more specific information about the radiation characteristics of musical instruments in a real performance situation.[4] Meyer's directivity data mostly provide directivity averages over the whole performing frequency range of the instruments. Very little information about the directivity of instruments for particular tones is included, even though in such cases the directivity changes dramatically over the performing range. Most of the data available on the directivity of musical instruments used nowadays for room acoustic simulations and auralizations consider the averaged directivities from Meyer's studies. Very few attempts have been made to study and use a different directional representation that would include the directivity changes of the musical instruments within the performing range.[5,6] On the other hand, experiments using room acoustics auralizations have shown that the directional representation of sources in room acoustic simulations is important and changes in their directivity can affect the perceived sound in a room.[7]

In the context of a new representation of the spatial characteristics of sound sources in auralizations[6], this study is a first stage of investigations into the radiation of musical instruments and their representation. As it has already been mentioned, it is necessary to know how great the directivity variations of musical sources are in a performance situation and how important these variations can be acoustically and perceptually. Thus, the first goal of this study has been to measure and compare the directivities of three musical instruments in a performance situation. For this purpose, the traditional representation (averaged directivity) and, as opposed to it, a more realistic representation (directivities of tones) were taken into consideration as elements of the comparison. The second goal has been to use the measured and averaged directivities in order to create room acoustic simulations and thus evaluate their possible influence on the perceived sound using different room acoustic parameters.

II. MEASUREMENTS AND RESULTS

A. Directivity measurements

Three different classical musical instruments with very distinctive directional behaviors were used for the directivity measurements: a Bb clarinet, a Bb trumpet and a French horn. The measurements were carried out using simultaneous recordings of 13 microphones in an anechoic chamber at 45° intervals, 24-bit quantization, 44.1 kHz sampling rate and measured in octaves from 125 to 8000 Hz at a distance of 1.5 meters from the source. Short isolated tones played on the instruments with a similar intensity (mf) were measured over the whole performing pitch range. Figure 1 shows one of the performers playing a trumpet in the anechoic chamber during the measurements and Fig. 2 shows the recording/measuring setup in the horizontal and vertical planes.

FIG. 1.Trumpet player during the directivity measurements in the anechoic chamber.

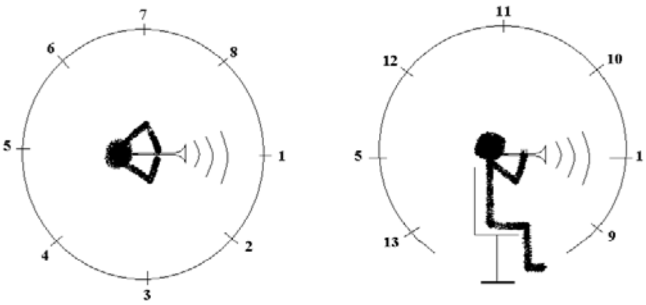

FIG. 2. Setup for the simultaneous directivity measurements with 13 microphones. The left part of the figure shows the setup in the horizontal plane and the right part shows it in the vertical plane. Microphones 1 and 5 appear in both planes.

B. Results

In order to compare the measured directivities short samples of the played tones were selected and used as representative. For each instrument three tones were randomly considered as representative in the low, middle and high pitch registers. The averaged directivities were calculated considering all the tones in the whole pitch register of each of the instruments. Figure 3 and Fig. 4 show the measured and averaged directivities for the three instruments at 1000 Hz in the horizontal and vertical planes. As shown in the figures, the directivities of the instruments show great variations from one played tone to the other. In some cases the instruments have a more narrow directional pattern while in others cases it is wider and less directional. Comparing the averaged directivities with the directivities of the tones for the different instruments, one can clearly notice that the differences are considerable in most of the cases, with some exceptions where the particular tones directivity resembles the averaged one. These differences proved to be greater for the vertical than for the horizontal plane.

III. THE DIRECTIVITY IN A ROOM

A. Room acoustic simulations

In order to see how the changes of the directivity of the above-mentioned musical instruments affect the sound in a room, computer room simulations were carried out with the measured and averaged directivities. The simulations were done using the software ODEON[8], assuming the same sound power for the sources, in a model of the concert hall ELMIA, located in Jönköping, Sweden. The acoustical parameters considered for the simulations in the room were the Sound Pressure Level (SPL), Clarity factor (C80) – determined by the ratio, expressed in decibels, of the energy in the first 80 milliseconds of an impulsive sound arriving at the listener's position to the energy in the sound after the 80 milliseconds, and the Lateral Energy Fraction (LF) – equal to the ratio of the weighted energy in the sound that does not come from the direction of the source to that which comes from all directions including that of the source.

B. Results

The results of the simulations in the room indicate a very distinctive sound distribution for each of the directivities of the instruments. Figure 5 illustrates the grid-response of the SPL for 1000 Hz simulated in the hall for three tones and the average considering the three instruments. The simulated fields show very different spatial distributions of the SPL in the room which can easily be related to the directivities in the horizontal axis shown in Fig. 3. In most of the cases the simulations with the averaged directivity show a more homogeneous and symmetrical distribution than the ones of the tones for the three musical instruments.

Figure 6 and Fig. 7 illustrate the grid response of the C80 and LF at the level of the audience in the room for the three tones and the average considering the three instruments. In both cases the spatial distribution proved to be similar to the one of SPL, but with greater contrasts and with the influence of the directivity of the sources even more obvious. The influence of the symmetry of the directivity of the sources becomes more evident especially in the distribution of the LF, where the reflected sound coming to the listener seems to be very dependent on the directivity.

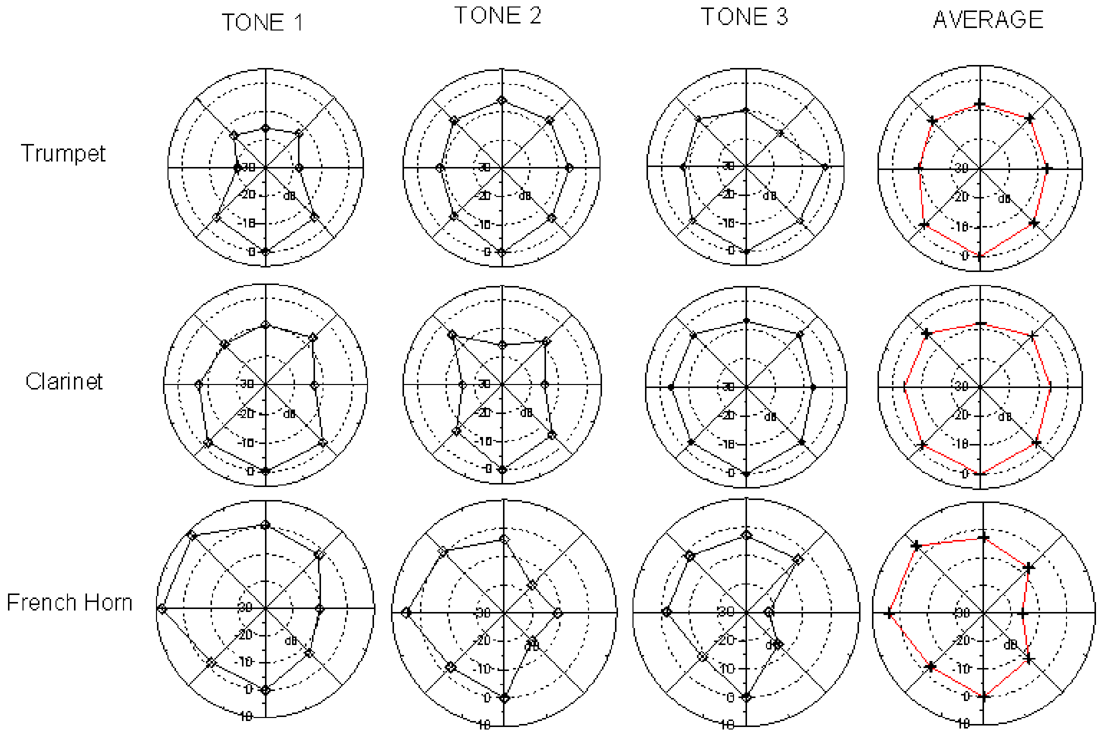

FIG. 3 Particular and averaged directivities for the trumpet, the clarinet and the French horn at 1000 Hz in the horizontal axis. The front of the instruments is facing down and in the case of the French horn the bell is facing the left side. The averaged directivity corresponds to the average over the whole pitch performing range of the instruments.

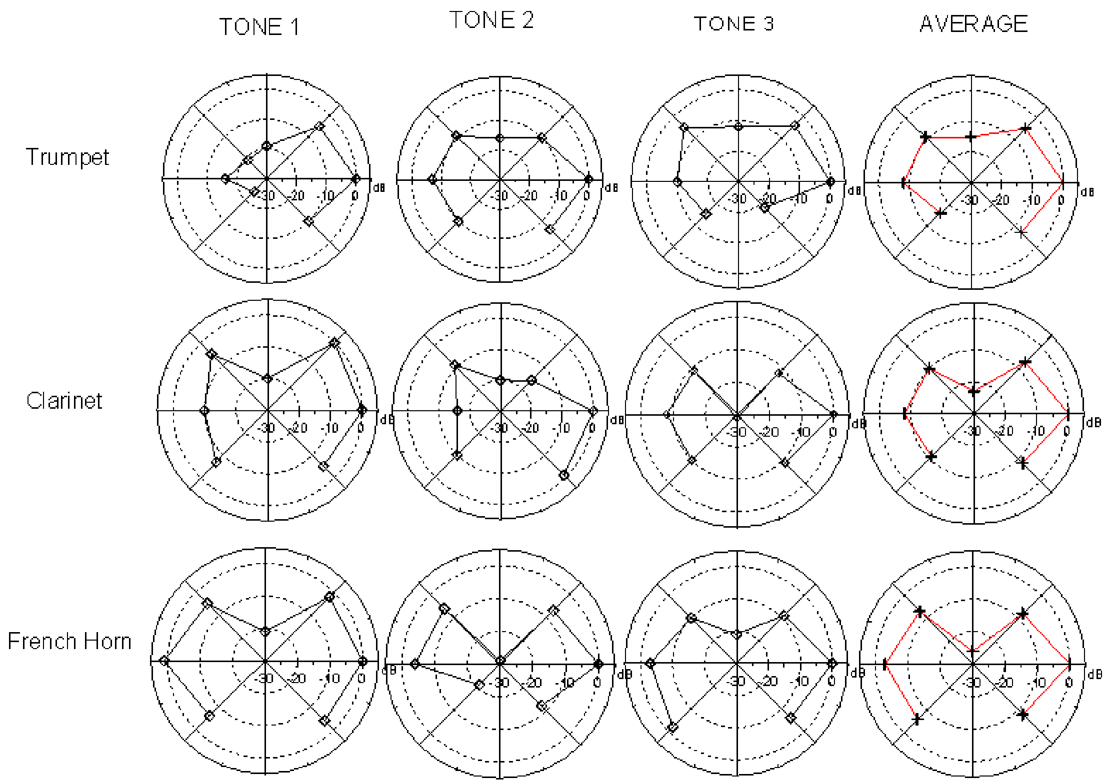

FIG. 4. Particular and averaged directivities of the trumpet, the clarinet and the French horn at 1000 Hz in the vertical axis. The right side of the figures corresponds to the front of the instruments. The averaged directivity corresponds to the average over the whole pitch performing range of the instruments.

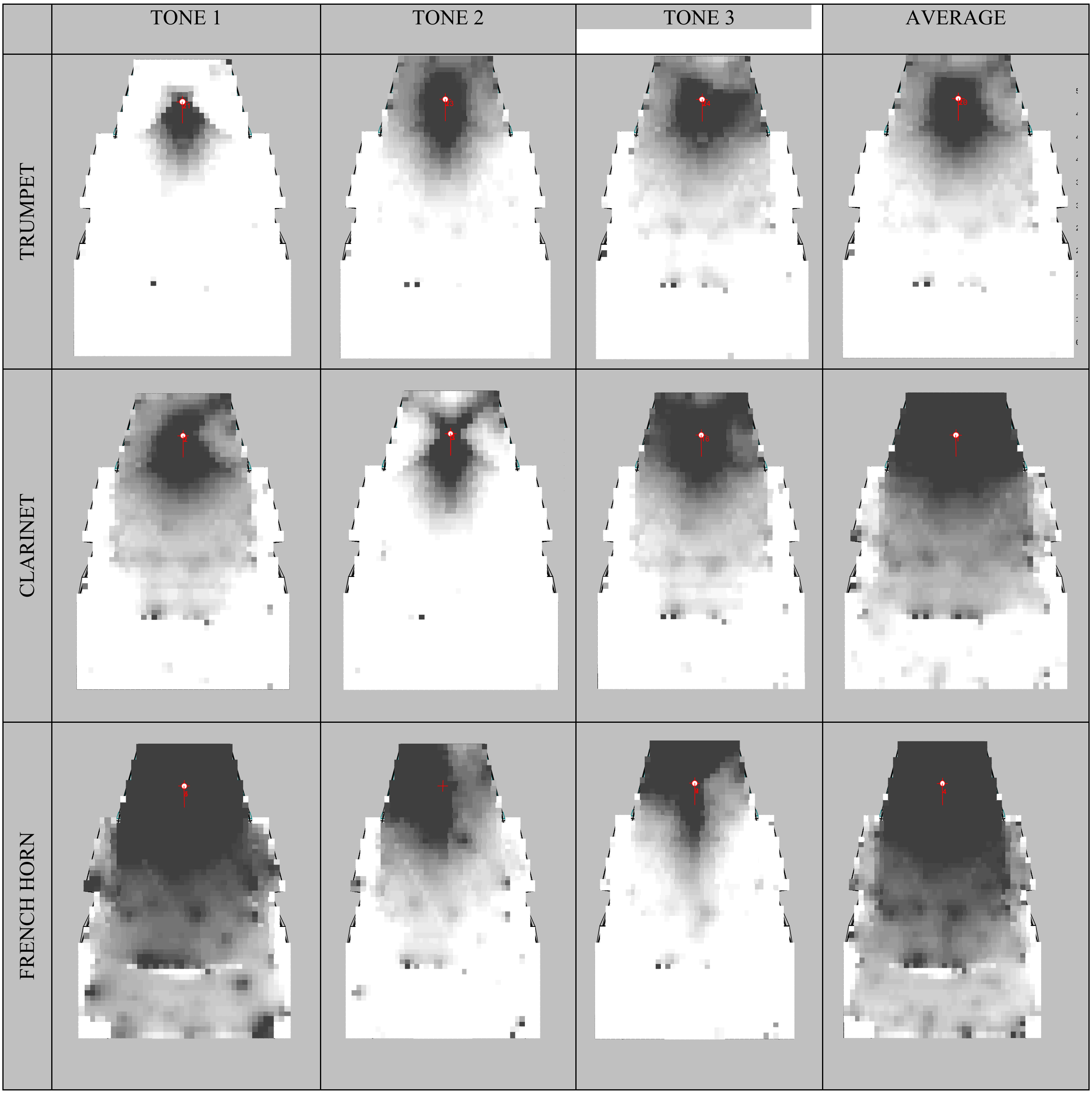

Figure 5. Grid-response of the sound pressure level (SPL) of the three musical instruments at 1000 Hz, simulated at the ELMIA concert hall with the directivity of three tones and the averaged directivity. The first three columns correspond to the directivity of the tones and the last column to the averaged directivity. The scale is relative and shown from 0 to 6 dB with white and black as the minimum and maximum values, respectively.

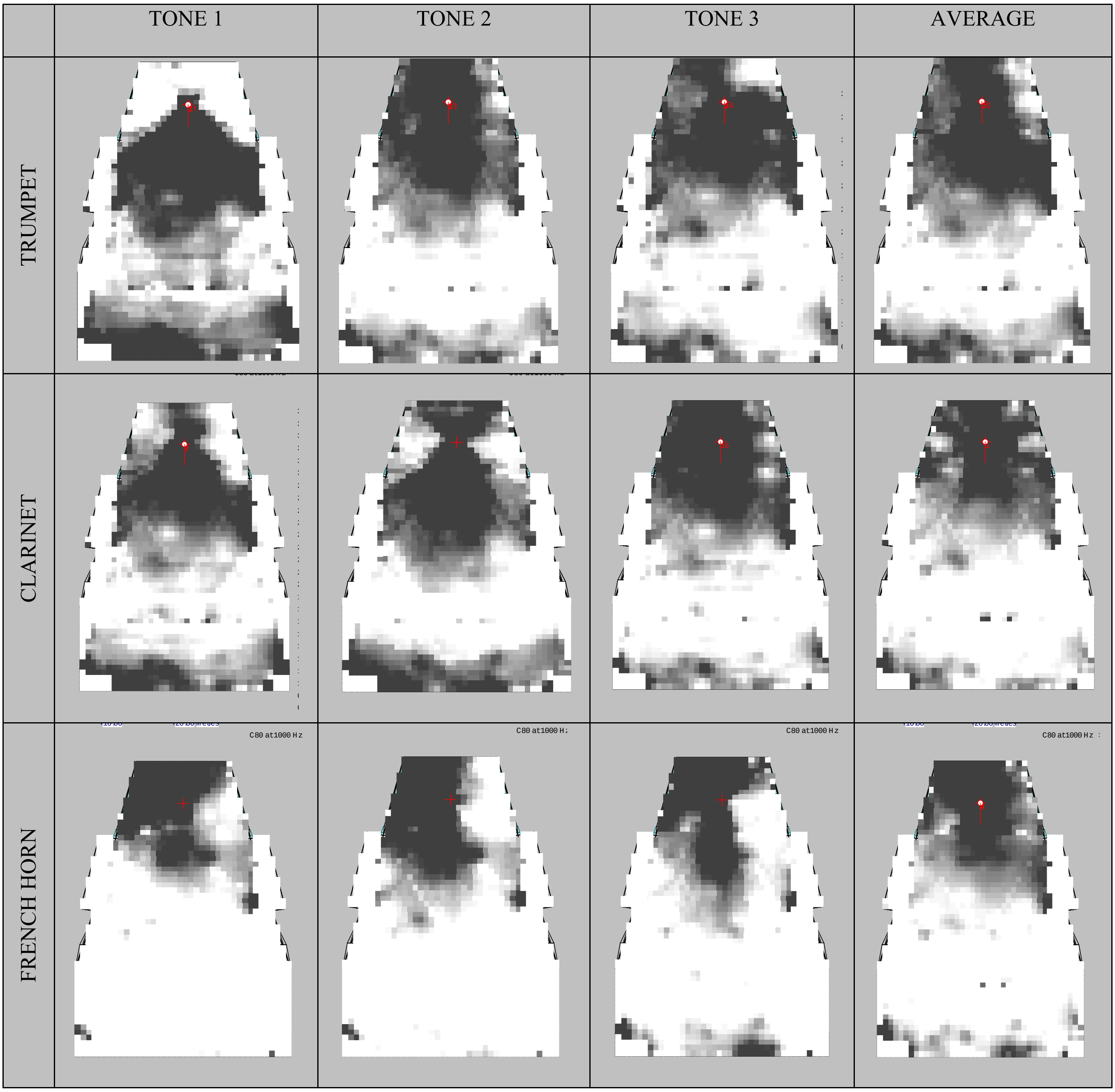

Figure 6. Grid-response of the clarity factor (C80) of the three musical instruments at 1000 Hz, simulated at the ELMIA concert hall with the directivity of three tones and the averaged directivity. The first three columns correspond to the directivity of the tones and the last column to the averaged directivity. The scale is shown from 0 to 4 dB with white and black as the lowest and minimum values, respectively.

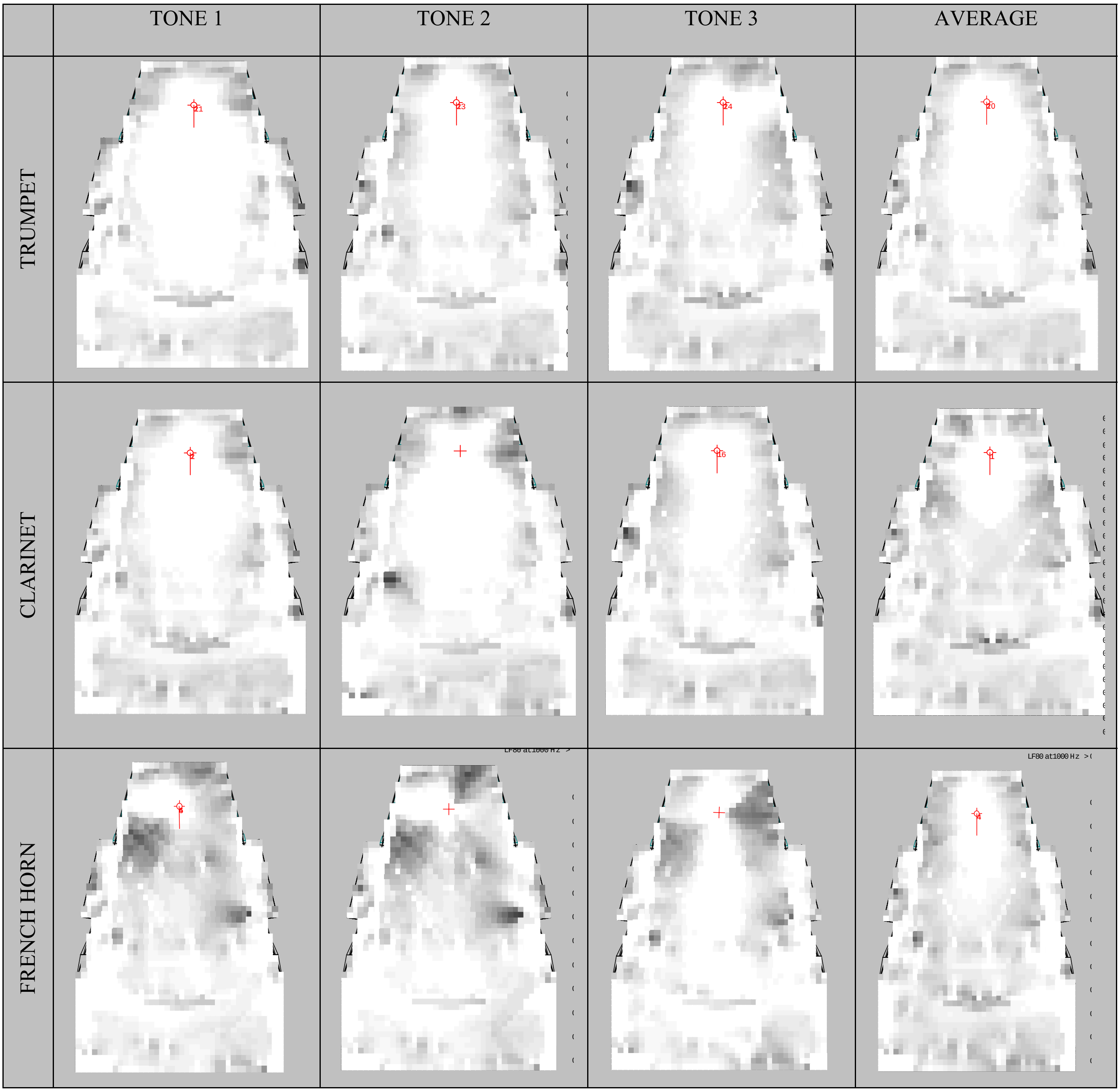

Figure 7. Grid-response of the lateral energy factor (LF) of the three musical instruments at 1000 Hz, simulated at the ELMIA concert hall with the directivity of three tones and the averaged directivity. The first three columns correspond to the directivity of the tones and the last column to the averaged directivity. The scale is shown from 10% to 50% with white and black as the minimum and maximum values, respectively.

IV. CONCLUSIONS

The directivities of tones played with three different instruments have been compared with the traditional averaged directivity used for representations. It has been shown that there occur large variations and diversity in the directional patterns of the tones. Room simulations using the measured and averaged directivities have proved that the directivity has a direct influence on the sound field created in the room according to acoustical parameters.

The use and practicality of other types of directivity representation for applications like room auralizations remains to be studied.

ACKNOWLEDGMENTS

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