Musician-oriented stage measurements in Italian historical theatres

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ABSTRACT

The Italian historical theatres have been built to blend the singer voice into the orchestral sound in the melodrama. In order to arrange the different scenes required by an opera representation, these theaters have a large volume in the stage area. Thus the stage volume may be oversized compared to the one of the orchestra pit. The paper studies the musician's perception in the Masini Theatre of Faenza when the stage is used by symphonic orchestras or smaller groups, making also the reference to similar literature concerning different theaters shapes. The impulse responses on stage have been measured and the monaural normal descriptors have been extracted. Numerical models of the stage are implemented in a hybrid-ray tracing software and an acoustic shell is designed. Questionnaires have been submitted to professional musicians and the answers have been statistically resumed. Hence acoustical measured descriptors, simulated values and musician answers are related and discussed.

1. INTRODUCTION

The Masini Theatre of Faenza (RA), was built in 1780-87, following the design of Giuseppe Pistocchi. The theatre was used in different ways: opera with singers, symphonic music, prose and also rock-pop (it hosts the main Italian festival of independent music). The theatre has an audience, three tiers of boxes and a gallery for a total amount of 500 seats. The theatre has never been qualified from an acoustical point of view and it represents a case study to evaluate the stage acoustics and the reliability of the numerical simulations of 18th century construction.

2. MEASUREMENT PROCEDURES

Monoaural measurements were made in the audience, in the boxes (with the source in various positions) and on the stage, to evaluate the acoustics among the musicians, varying the position of the source and of the two microphones in rotation. Two possible ensembles were simulated: a trio, identified with three positions representing the members of a trio (T1, T2, T3), and a classical orchestra of about 30 items, where five positions for the sections of the orchestra were identified, simulating their acoustic focal point of these sections: first violins (VL1), second violins (VL2), violas (V), cellos (C) and woodwinds (F). The source was placed in each position and the measurements were made in all other points of the group. From the impulse responses, measured with MLS technique and processed in Matlab, it was possible to determine the monaural criteria Δt_1 and T_{sub}.

Table 1. Synthesis of the characteristics of the Masini theatre stage

width (m)	9.8
area (m^2)	98
slope (%)	7
mean Δt_1 (ms)	23
mean T_{sub} (s)	0.83
mean A	0.83

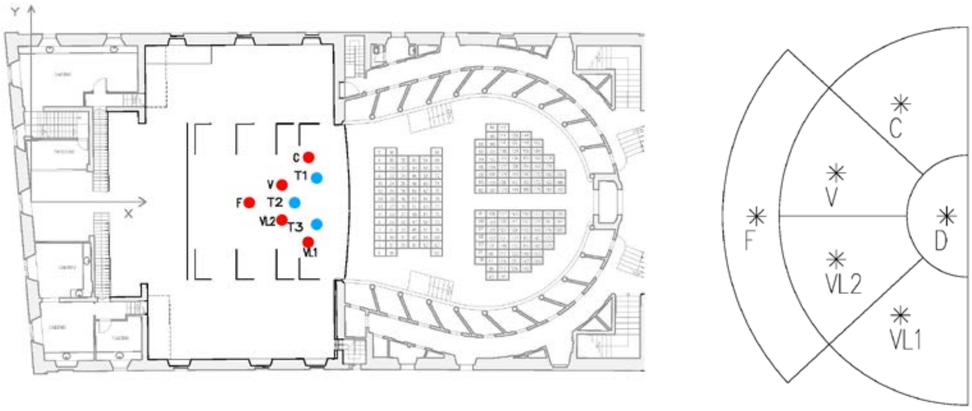

Figure 1. Masini Theatre, positions of sources representing a trio (T1, T2, T3) and a classical orchestra (VL1, VL2, V, C, F).

3. IMPRESSIONS OF THE MUSICIANS ON THE ACOUSTIC CONDITIONS

A questionnaire was distributed among the musicians and conductors of Emilia-Romagna, structured with reference to those drawn up by Dammerud [1,2], adapting some questions to the characteristics of the Italian theatre stages. The questionnaires were divided into two parts: the first section investigated the gender, age, instrument played and experience in symphony orchestras or chamber groups (figure 2), then some questions followed to understand the importance of acoustic parameters and the general situation of musicians and conductors on the stage. In the second section specific questions about the studied theatre were asked [8]. Some questions were open while others were multiple choice; in the evaluation of the quality of the room, artists were asked to choose on a scale from 1 to 5. The questionnaire was distributed to various conductors and musicians, covering all instruments. The analyzed theatre does not have a permanent orchestra; the interviewed musicians are experienced professionals who play in this theatre as needed. 63 people were interviewed, including 52 men and 11 women, aged between 22 and 55 years.

Comparing the results of the measurements performed on stage and those in the hall, differences are noticed. The measured values on stage confirm the preferred use for opera singers ($\tau_e \approx 35$ ms). The preferred values of Δt_1, due to higher value of A (see table 1), depend on coefficient c [6]:

$$[\Delta t_1]_p = \left(\log_{10} \frac{1}{k} - c \log_{10} A \right) \tau_{e,\min} \quad (1)$$

In both cases the measured values are incongruent with the preferred values for symphonic music (τ_e > 70 ms). This may confirm the test results, in which the players declare to feel a low reverberation and a low sustain of the instruments when the stage is used for symphonic music. It suggests the need of an improvement of the stage acoustics that could be reached by designing an acoustic chamber.

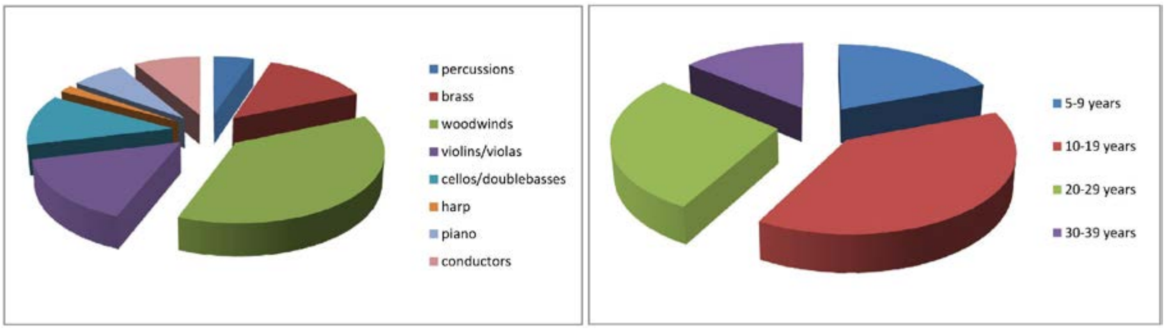

Figure 2. Instruments played and years of experience in orchestra or chamber groups of interviewed musicians

4. ALGORITHMIC DESIGN OF A NEW ACOUSTIC CHAMBER

The goal was to increase the reverberation on the stage and to focus the first reflections on the gallery, the third and fourth tiers in the hypothesis of non-diffusive surfaces. In order to optimize the geometry of the reflectors, an evolutionary solver was used: *Galapagos*, a plug-in for *Grasshopper* that automatically converts the requirements into a constrained optimization problem and then solves the problem using optimization techniques (Fig 4). The constrained optimization problem iteratively simulates the geometry, compares the results of the simulations with the constraint objectives, and uses optimization methods to adjust the tuned parameters to meet the objectives. The number of rays that the source emits in order to generate each single nurbs curve is about 500. The fitness function for the central boxes converges with 300 intersections. For the lateral boxes, the value of the intersections is 250. After all nurbs curves were created, they were lofted in order to generate the reflector. The reflectors created in this manner are four and each of them is hung at different heights (Fig. 5). The so created acoustic chamber was simulated with Odeon (Fig. 3), placing sources and receivers on the stage. The results of the simulations (Fig. 7) confirm higher reverberation on the stage with the acoustic chamber, following the performers' suggestions.

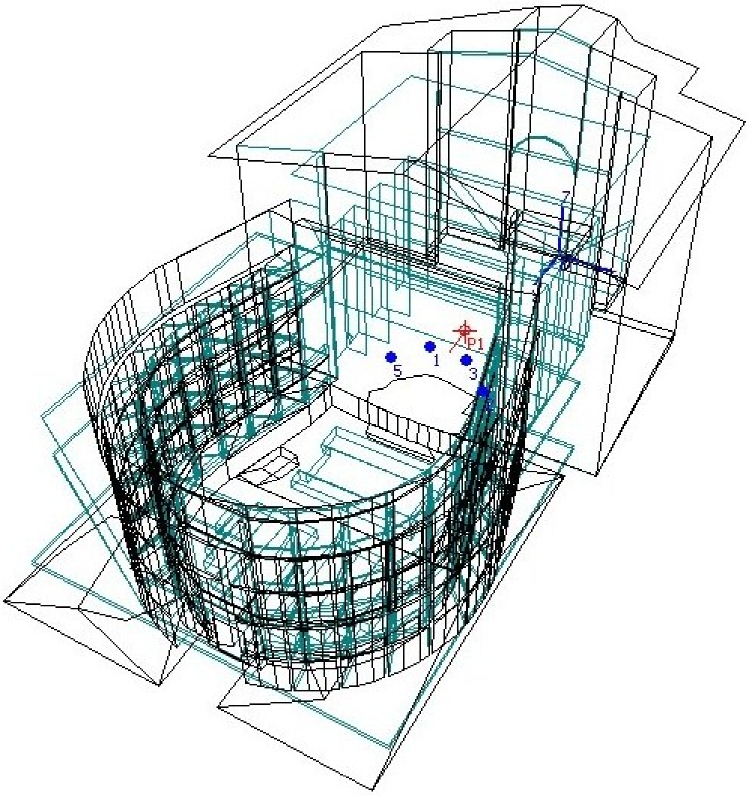

Figure 3. Odeon model of the Masini Theatre

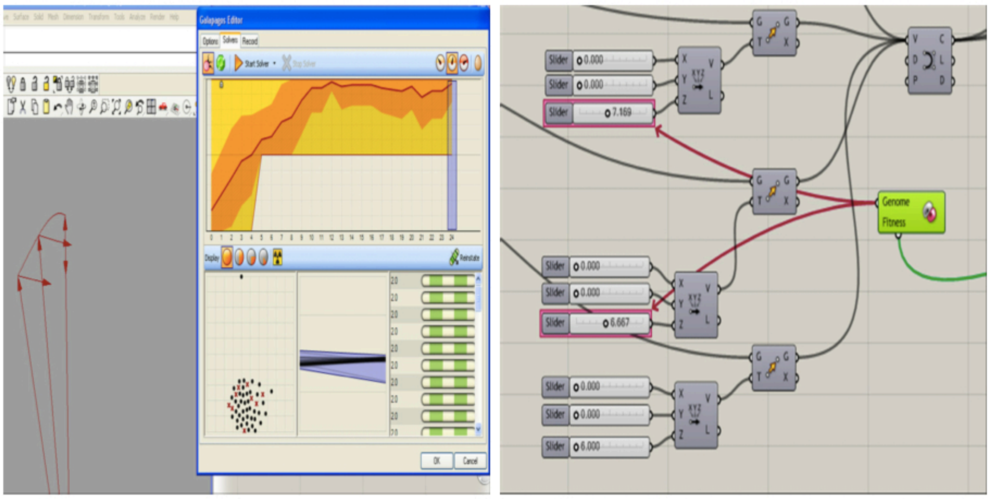

Figure 4. Galapagos screenshots of the algorithmic design of the acoustic camera

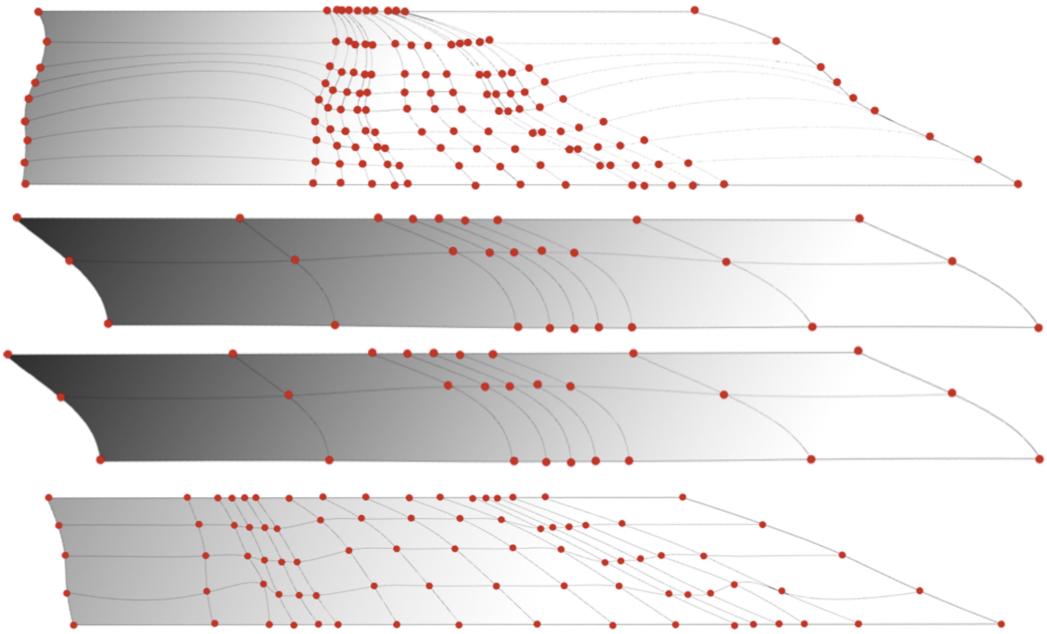

Figure 5. Wireframe design of the acoustic camera ceilings

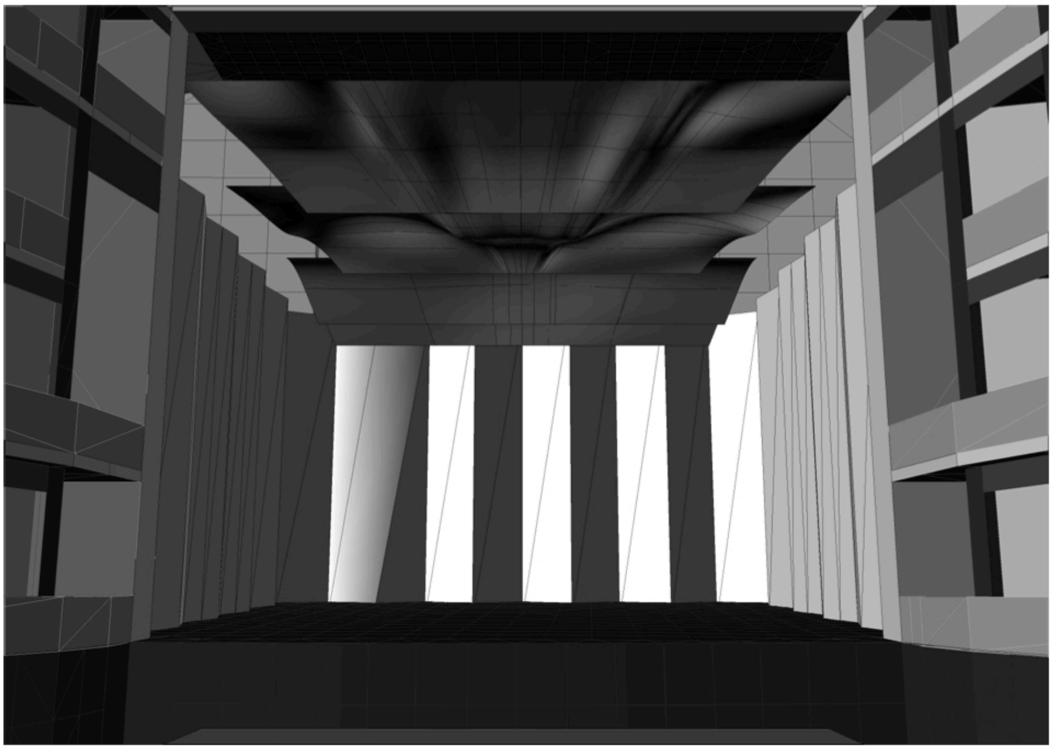

Figure 6. 3D view of the acoustic camera from the audience

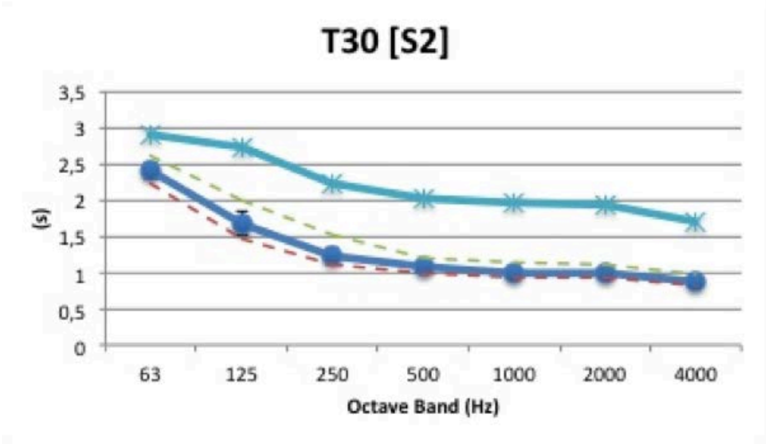

Figure 7. Comparison between the simulated stage values of the reverberation time without (blue curve) and with the acoustic chamber (light blue curve)

5. DISCUSSION

The objective parameters measured on the stage can be compared with the results of the questionnaires. The values of T_{sub}, evaluated on the stage, seem to confirm the fact that the T_{sub} values are too low when playing symphonic music (τ_e >70 ms). It authorizes to design a new acoustic chamber, that improves the reverberation on stage and focuses the first reflections to the high tiers of boxes. It should also be noted that there are some differences between this work and the others in literature; for example the analyzed theatre doesn't have a permanent orchestra, the interviewed musicians are experienced professionals who play in this theatre as needed. This is relevant for two aspects: the first one is the time gap between now and the last time that the musician played in the considered theatre and the second one is that it is possible that one musician hasn't acquired yet an acoustic experience about the theatre to modify his/her approach. Furthermore the number of collected questionnaires is lower than other studies in literature [2].

5. CONCLUSIONS

In this study, measurements of the acoustic qualification of the stage were made in an historical theatre. Measurements for the acoustic qualification were performed recording the impulse responses in two configurations representing a trio and a classical orchestra. Reverberation time T_{sub}, and Δt_1 were calculated and analyzed.

In order to compare the obtained results with the real perception of the musicians, a questionnaire was distributed to professional musicians of the territory and the results of these questionnaires were then processed.

Both measurements and performer's answers suggest the need of an higher reverberation time on the stage.

An acoustic camera was designed in order to improve the acoustic on the stage and also to have more reflections directed towards the 4th order of the theatre. An algorithmic design procedure was tested and simulated with Odeon. The results confirm an higher reverberation time on the stage with the acoustic chamber.

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