An acoustic catalogue of historical Italian theatres for opera

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The renovated interest for opera and opera houses in the last fifteen years has stimulated many studies about the objective acoustics of these theatres. Until the eighties the reverberation time was the only acoustic parameter considered for the objective description of their acoustics. Borrowing and expanding the existing knowledge about concert hall acoustics also the world of the opera houses has been provided with further parameters to describe their acoustics. Many opera houses and theatres were conceived for almost three centuries in the style of the Baroque theatre. Opera and its commercial success were borne in the first half of the 17th century in Italy. Italian architects started to modify and build anew theatres in the above mentioned style which revealed themselves suitable for opera performance. Although reconstructed or recovered, many historical Italian theatres have survived since the first half of the 18th century. A number of them hosts opera performance regularly. Nine acoustic research teams from nine Italian Universities share the task of the compilation of an acoustic catalogue of a representative sample of historical Italian theatres for opera under the coordination of the author who will report his proposals about the contents of the above mentioned digital catalogue.

1 Introduction

Historical theatres constitute a rich architectural heritage which is spread throughout Italy. They were cultural landmarks for the communities that built them in the past and still are for today communities that take care of their survival. During the recent years the Italian-style theatres have received a particular attention by acousticians interested in the documentation of their objective acoustic features. The aims of the interests are of various genres (e.g. the subjective ranking of theatres according to their fame in the aim to correlate the judgements with objective acoustical descriptors of their sound quality [1]; the certification of their objective acoustics before any modification, restoration or reconstruction [2]). These theatres can be considered a development of theatres built in Italy during the Renaissance age [3]. Renaissance theatres were large rooms whose interiors were inspired by open-air ancient theatres of Greek and Roman times. The public performance of opera started in the first half of the 17th century. Its commercial success stimulated the modification and construction of theatres for the purpose, both in Italy and elsewhere. The horseshoe, the elliptical, the circular and the bell shaped plans with boxes in the walls were the auditorium shape preferred by many Italian architects of the time. This basic theatre form was adopted also elsewhere becoming a classic choice for about three centuries. Baroque theatres revealed themselves suitable for opera performance since its birth.

MIUR (Italian Ministry of Education, University and Research) has granted funds to research teams of nine Italian universities in order to deepen the knowledge about some topics concerning the acoustics of large rooms for music performance. A central task shared by all the research teams is the compilation of a sort of acoustic catalogue of a representative sample of historical theaters for opera which are spread all over the national territory. This was one of the good reasons why nine teams located at various latitudes joined in the task.

The author has taken the responsibility to coordinate the project and reports about his proposals for the compilation of the catalogue. It implies the collection of information of various genres: historical, architectural, artistic and, chiefly, acoustical. Acoustic measurements are still in progress in the selected theatres by taking into account the latest findings about the description of opera house acoustics in its major known facets. Acoustic parameters will be reported and row impulse responses will be included in the catalogue in digital format. At its completion a number of copies of the catalogue will be available to other researchers interested in the study of acoustics of classical Italian opera houses.

This note is based on the data of the “Teatro di San Carlo” in Naples (Italy) which was collected by the research team of the DETEC – University of Naples Federico II. This research team has taken the duty of collecting the data also for the “Teatro dell’Opera” in Rome. The research teams of the further eight Italian universities are engaged in the collection of data of other theatres. At the moment it can be estimated that the catalogue will contain data for a total of eighteen theatres.

2 Contents of the catalogue

Video. A short video will introduce the visitor into the auditorium of the theatre giving him the general
impression of the room. Special details will be zoomed on.

**Historical notes** will describe the origin of each theatre and its evolution up to contemporary times.

**Architectural data.** Plans and sections, as available at the technical management office of the theatre, will be reported. They will be downloadable in a digital format. A brief description of the nature of materials which constitute the boundaries of the auditorium will be given. This will be complemented with photos which will illustrate interesting details and both the stage house and pit set-up as seen when the measurements where carried out, in particular.

**Artistic notes.** A brief about the main events hosted in the theatre will highlight its artistic life.

**Acoustic data.** Nine listener location in the stalls and five receiving locations at higher levels in the boxes with at least two sound source locations have been considered: one on the stage and one in the orchestra pit. For each sound-source/receiver pair suitable impulse responses have been recorded. Major room-acoustics objective descriptors according to the document ISO 3382 will be reported with a clear identification of each pair of sound-source and receiver in the plan and in the section of the theatre. All the impulse responses in a digital format (.wav) will be enclosed and retrievable easily.

**Instrumentation.** A brief description of the instrumentation features, of its set-up and of the software used for data acquisition and its processing will be given.

### 3 Highlights

![Figure 1: Opening frame.](image)

At the start a frame will appear like the one in Figure 1. It reports the name of the participating Universities and their logos. A double choice is allowed. By clicking on the label of a participating University a path is followed which will lead to the section which each University team has taken care of completely.

Alternatively, a click on “Theatres” will show a frame reporting the names and location of all the included theatres. As an example, if the choice is “University of Naples”, the frame in Figure 2 will appear.

![Figure 2: Name and location of the theatres included in this catalogue by the team of the University of Naples.](image)

A click on the name of the desired theatre will open its section directly. Suppose that the Teatro di San Carlo is selected. A frame will appear like the one in Figure 3. Now, it is possible to follow the flow of the contents as itemized at the bottom the frame, that is the video visit, the photographs, historical notes, architectural data and so on.

![Figure 3: Opening frame of the Teatro di San Carlo.](image)

Otherwise, a click on a particular item will lead to the selected subsection; e.g., by clicking on the active label...
“Acoustic measurements” a plan of the Teatro di San Carlo” will appear (Figure 4) where the locations of the sound sources and receivers are reported. By clicking on “Sound source” a sound source, either on the stage or in the orchestra pit, can be selected. A click on a receiving point, either in the stalls or in a box, will define a pair of sound source and receiver which is identified with a label like “Stage, row number and seat number”. Now, the visitor is looking at the set of acoustic data related to the selected source-receiver pair (Figure 5).

![Figure 4: Selection of a sound source-receiver pair.](image)

Figure 5 displays a number of tables reporting the objective octave-band room-acoustics parameters obtained from single channel and two channel paired impulse responses.

![Figure 5: Frame reporting calculated room-acoustics parameters.](image)

The small symbols at the right side over each table remind that the data were obtained from the output signals of an omnidirectional microphone, an omnidirectional microphone plus a “figure of eight” microphone, two omnidirectional microphones at the ears and, finally, by a sound level meter.

By clicking on the active buttons (denoted by the symbol of an impulse response) at the left of each table, a graphical representation of the relevant wideband impulse response will appear in a new frame (Figure 6). It is useful for inspecting the time-history of the impulse response wherefrom the parameters pointed by an arrow were calculated.

For example, Figure 6 shows the wide band impulse response from which the room-acoustics parameters in the uppermost table in Figure 5 were calculated. The identification of the sound source-receiver pair is also reported.

![Figure 6: Wide-band impulse response.](image)

The first column of tables like those in Figure 5 is constituted of active areas. A click on each area will open a frame containing the diagram of the relevant objective descriptor as a function of frequency. As an example, Figure 7 shows the effect of the click on EDT.

![Figure 7: Diagram showing a room-acoustics descriptor as a function of frequency related to a specific sound source-receiver pair.](image)
It is to be pointed out that the team of the University of Naples obtained the Sound Strength G on the base of steady-state SPL measurements as determined in the auditorium by a known sound power level radiated by the omnidirectional sound source which will be described in the “Instrumentation” section of the catalogue. Therefore, no impulse response is associated with G.

An important subjective aspect of the sound quality in Opera Houses is the balance between the voice of the singer and the sound which reaches the listener from the orchestra pit [4, 5, 6]. No objective descriptor of the balance has received a widespread consent yet. The one that seems to gain some preference is the difference between the sound level caused by a sound source on the stage and the sound level at the same listening location caused by a sound source in the orchestra pit. Both sound sources should radiate the same sound power. Many questions are still waiting for a solid answer, e.g. what kind of directivity can be normalized for the sound-source on the stage? and what in the pit? And so on.

With this state of matters, the team of the University of Naples decided to carry out all the measurements with an omnidirectional sound source. However, steady state descriptors of the balance (SPL difference) can be calculated on the base of the values of G for the same receiving location measured with the sound source on the stage and in the pit.

A click on the button “Download” in the frame introducing a theatre, e.g. Figure 3, leads the visitor to a download section where all kind of digital data can be retrieved, impulse responses included.

4 Conclusion

It is the hope of the author that this “acoustic catalogue” of a significant sample of Italian style historical theatres will be completed as soon as possible and will fulfil the intents which stimulated the participation of all the researchers who joined in the task. However, he is aware of the difficulty to gather perfectly homogeneous data from nine different research teams. The catalogue is to be considered as a proposed container where each participant can display his contribution and creativity.

It is the opinion of the author that, notwithstanding inevitable drawbacks, the catalogue will be a long lasting source of information which will stimulate further studies on these progenitors of the theatres and Opera Houses of the modern times.

5 References