

# Virtual acoustic reconstruction of the church at the lost monastery of Santa Maria de la Murta

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**Abstract.** Archeological acoustics is a part of acoustics that studies ancient environments which were dedicated (completely or partly) to sound performing. The combination of this acoustic area in conjunction with room acoustics enables the study of the acoustic evolution of existing buildings (in terms of the historical documentation) or even, make the acoustic reconstruction of rooms which were destroyed or they are in a bad state or in ruins. In this work, an acoustical reconstruction of the church of the Hieronymites' monastery of the Murta from the XIV century, in Alzira, Spain has been developed. This building was abandoned in 1836 and now is in ruins. The work develops a geometrical model, together with a proposal of materials which were common in the churches of the same area, an acoustical study and finally an auralization of a choral performance has been done (as this monastery had its own musical chappelle).

## 1 Introduction

Acoustical archeology aims to study previous acoustical stages in buildings or rooms or to recover old rooms, environments or buildings that has been lost. This part of the acoustic science also tries to analyze the historic acoustic evolution of emblematic buildings of our Cultural Heritage.

The main aim of this paper is to make a virtual acoustic rehabilitation of the ruined church of the Hieronymite's monastery of Santa Maria de la Murta, according to several graphical and written documents.

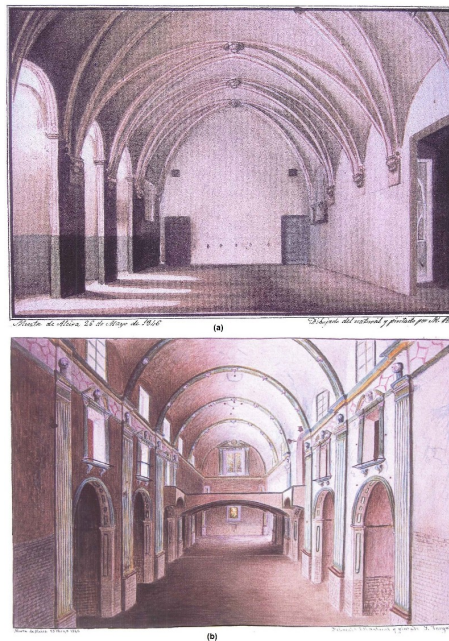
### 1.1 Brief historical notes

The main purpose of this work is to retrieve the acoustics at the last stage of a Hieronymites' monastery. The ruins of this monastery are located in the Valley of the Murta (also called the old Valley of Miracles) at coordinates WGS84 (Latitude, Longitude): 39.128970, -0.361079. The monastery was founded in the

14th century by a group of monks coming from another monastery in the zone (Sant Jeroni de Cotalba). The building was ready in the second half of this century, thanks to several donations. [1][2]

One of the main patrons of this monastery was Lluís Vich Corbera, a “Mestre Racional” in the city of Valencia (this was the person in charge to control the treasurers in the Aragon Crown and the Kingdom of Valencia, this person also was in charge of all the counts of the kings and nobles). He donated many artworks and was buried in the church of this monastery.

The first church of the monastery (painting shown in Figure 1a) was located in the actual sacristy, which was in the place occupied by this vestry room after building the new church that was projected in 1516 by Guillén Ramón Vich (Archbishop in Xativa) and was finished in 1623. This long time was mainly due to some economical problems of the community of monks. The new church (painting shown in Figure 1 b) was next to the old church, so this place was used as a sacristy. [1]



**Fig. 1.** Paintings of the sacristy (old church) (a) and the new church (b) from 1846 and painted by M.Peris.

## 1.2 Architecture of the lost monastery

The architecture of the new church shown a traditional building as a nave with chapels between counter-forts. A high choir at the feet and a high chancel was inherent to mendicant orders, as the Hieronymites. A cut in elevation showed the austerity of the classical architecture of the 15th century, only enriched with some tiles at the skirts of the church and some polychrome plaster rosettes [1].

This is an architecture that seeks the economy in the use of materials, which is a clear inheritance of the new mentality that comes after the Council of Trent and comes from the founder frantic activity patriarch Joan de Ribera. The orders and arches were made with stone, the walls made with masonry and the doorposts and vaults made with brick, although they were coated with some kind of plaster.

The use of brick allowed a reduction in costs and a faster construction. It was adapted to traditional forms (i.e. walls, vaulted ceilings, etc) and subsequently to other aimed at sphericity, which were made in Italian style, but also had reminiscences from the Valencia late-Gothic style. The bricked pendentive vaults were widely used in the Valencian architecture in the first half of the 16th century. The type of closure in the church of the Murta came at a turning point between the prevalence of these and barrel vaults with lunettes.[1][3]

After the confiscation of the properties of the Spanish Church in 1836 by Juan Álvarez Mendizábal, ministry of the regent queen María Cristina de Borbón, the monastery was abandoned and sold to private owners who left the building in a state of ruin.

## 2 Methodology of the virtual acoustic rehabilitation of the new church of the monastery

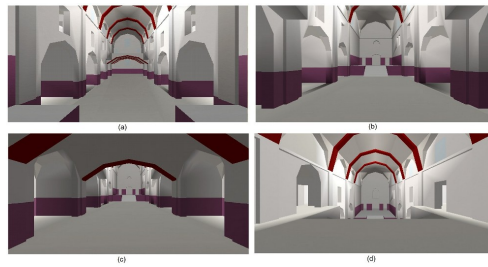
A geometrical model of the new church of the monastery has been developed using a CAD software. For this purpose, a measurement campaign was done in January, 2014. Figure 2 shows some photographs where the current state of conservation can be seen. This measurements were made with a handy laser rangefinder device.

The materials used were related to the referred in the bibliography of the monastery. At this moment, a specific study of the 'in-situ' materials has not been done yet, but it is scheduled by the end of September. The materials in Table 1 have been selected from the bibliography [4], taking into account the descriptions of the church in [1] [2] [3]. The model has been acoustically simulated by using the ODEON software [5]. In Figure 3, several views of the model of the church have been taken. The simulation has been done without taking into account the lining of the church (i.e. statues, paintings, altarpieces, organ, etc), because the model consider the last situation of the room in 1846 when the room was empty.

An omnidirectional source has been used in the simulation, located at the position (9.000, 28.000, 3.800). The receivers were located in the positions collected in Table 2. They are shown in Figure 4.



**Fig. 2.** Photographs of the current state of the church of the monastery. (a) Frontal part of the church with arch and the pigeon's tower. (b) Part of a side chapel (broken altar, some tiles on the floor and parts of plaster on the wall). (c) Measuring the height of the arches. (d) View of the back part of the church (similar view as in Figure 1)



**Fig. 3.** Different views from the simulated model in ODEON: (a) view from the altar, (b) view from the middle of the church, (c) view from the back of the church, (d) view from the choir.

**Table 1.** List of materials and absorption coefficients in the church based on frequency (in Hz).

Material	125	250	500	1000	2000	4000
Rough concrete	0.02	0.03	0.03	0.03	0.04	0.04
Ceramic tiles	0.01	0.01	0.01	0.01	0.02	0.02
Door wood	0.14	0.10	0.06	0.08	0.10	0.10
Crushed stone	0.41	0.53	0.64	0.84	0.91	0.63
Simple Glass	0.08	0.04	0.03	0.03	0.02	0.02
Wall plaster	0.02	0.02	0.03	0.04	0.05	0.05
Ceiling Plaster	0.02	0.03	0.04	0.05	0.07	0.08

**Table 2.** Positions of the 6 receivers in the church.

Rec Nr	X	Y	Z
1	8.00	12.00	1.70
2	8.00	15.00	1.70
3	8.00	18.00	1.70
4	10.00	18.00	1.70
5	10.00	15.00	1.70
6	10.00	12.00	1.70

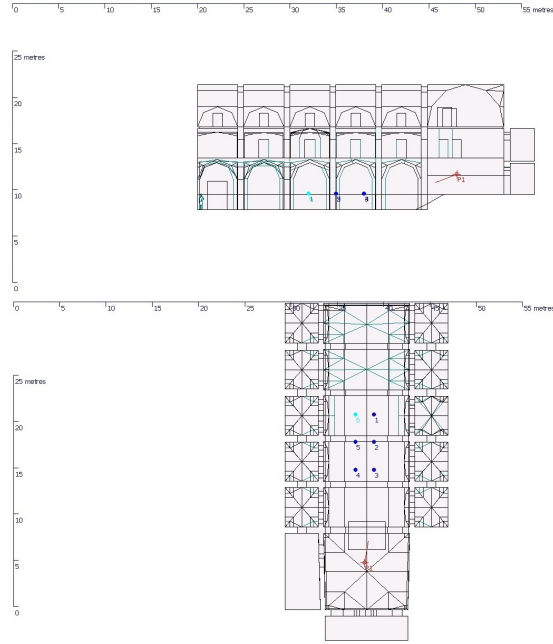
Also the graphical model has been developed with 3DMax Studio with textures, based on the documentation and the graphical information collected in-situ, in order to integrate auralization, by this moment as a video. This model is being transformed to IVE format in order to be easily integrated in an OSG navigator (or even in a CAVE). Figure 5 shows some captures of the texturized model.

### 3 Results and discussion

After the acoustic simulation, the first result shows an average EDT reflected in Figure 6 and the statistics for RT30, C80 and D50, are shown in Tables 3, 5 and 4.

**Table 3.** Statistics of RT30 for the 6 receivers.

Frequency	125	250	500	1000	2000	4000
Minimum	6.81	6.05	4.83	3.85	3.00	2.29
Average	6.83	6.06	4.84	3.87	3.02	2.32
Maximum	6.84	6.07	4.86	3.88	3.06	2.34



**Fig. 4.** Plan and section of the building with the receivers and source.

**Table 4.** Statistics of D50 for the 6 receivers.

Frequency	125	250	500	1000	2000	4000
Minimum	0.05	0.05	0.06	0.08	0.11	0.14
Average	0.06	0.07	0.08	0.10	0.13	0.17
Maximum	0.07	0.08	0.10	0.12	0.15	0.19

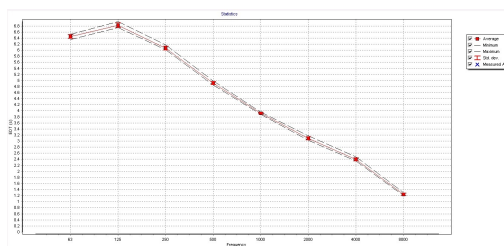
These results make obvious that this church (with  $8000 \text{ m}^3$  aprox.) was reverberant enough and the use of coating was necessary for different purposes (preaches, musical services, etc.). According to the empiric formula for the optimum reverberation time by Pérez-Miñana [6] for music at churches ( $T_{opt} = 0.99 \cdot \sqrt[3]{V}$ ), this optimum reverberation time is 2.2 seconds, so the reverberation time of this church when the monastery was abandoned was higher than its optimum value.

#### 4 AURALIZATION OF A MUSICAL EXCERPT

One of the most important features of the acoustical simulation is the possibility to obtain the impulse responses and thus to get auralizations of this lost building. The church of the monastery of “Santa Maria de la Murta” has remained silent for a very long time, and now, music can be listened in this environment. For this



**Fig. 5.** Texturized model for graphical representation into a video or an immersive device.



**Fig. 6.** EDT obtained in the simulation.

**Table 5.** Statistics of C80 for the 6 receivers.

Frequency	125	250	500	1000	2000	4000
Minimum	-9.8	-9.2	-8.2	-7.0	-5.7	-4.3
Average	-9.1	-8.6	-7.6	-6.5	-5.2	-3.8
Maximum	-8.7	-8.2	-7.2	-6.1	-4.9	-3.4

work, a choral piece has been selected to be auralized in this environment. This piece was composed by one of the Lluís Vich de Corbera’s grandsons (also named Lluís Vich) for a religious drama, called “Misteri d’Elx”, based on the burial of the Holly Virgin. This drama was declared Intangible Cultural Heritage by the UNESCO in 2001. This piece is called “Ans d’entrar en sepultura” (“before entering to the burial place”) and it is for a men choir without instruments. This piece was performed by the Capella del Misteri (current performers) in February 2014, and recorded with a binaural head (HeadAcoustics) in a dry environment. The auralization was made in the position 1 of the Figure 4 and the audio can be heard in [7].

## 5 Conclusions and future work

In this work, a model of a lost building has been developed. This building has been acoustically simulated taking into account the dimensions of the ruins and the historical documentation. This first approach to the virtual acoustic rehabilitation of the monastery of “la Murta” has shown that the room had a high reverberation (RT30) and a poor definition for speech (D50), which is better at high frequencies.

Also the auralization of a choral work by Lluís Vich (grandson of one of the patrons of the monastery) has been done. This auralization has been performed within the empty church, without any ornament as this was the situation in 1846 when M.Peris make his paintings (shown in Figure 1).

This work is going to be extended by adapting this model to an OSG navigator and connecting a head-tracking with headphones system in order to detect the movement of the listener, adapting the sound according to the correspondent HRTF and interpolating between the different impulse responses in the room, pre-calculated from the acoustic model.

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## References

1. L. Arciniega: Santa María de la Murta (Alzira): Artífices, Comitentes y la “Damnatio Memoriae” de D. Diego de Vich. Simposium Los Jerónimos: El Escorial y otros Monasterios de la Orden. San Lorenzo de El Escorial, Instituto Escorialense de Investigaciones Históricas y Artísticas, vol. I, pp. 267–292 (1999).
2. J.B. Morera: Historia de la fundación del Monasterio del valle de Miralles y hallazgo y maravillas de la Santísima Ymágen de Ntra. Sra. de la Murta. Año 1773. Publ. Ajuntament d’Alzira (1995).
3. L. Tolosa, M. Framis: Santa María de la Murta. Arquitectura d’un cenobi medieval. VI Assemblea d’Història de la Ribera (1993).
4. ODEON: Acoustic absorption data. URL: <http://www.odeon.dk/acoustic-absorption-data> (visited in 29/04/2014).
5. C.L. Christensen: Odeon Room Acoustics Program, version 10.1, User’s Manual, Industrial, Auditorium and Combined Editions, Lyngby, Denmark (2009).
6. M.Fernández, M.Recuerdo, D.Cruz: Church Acoustics. (RBA-05-015) Proc. Forum Acusticum, Seville (2002).
7. Auralization of “Ans d’entrar en sepultura” by Lluís Vich in the church of Santa Maria de la Murta (URL: <http://goo.gl/cEzplN>)