The conservation of acoustical heritage

Zerhan KARABIBER

Summary

In the conservation and restoration of historical monuments, usually only concepts related to visual aesthetics are taken into consideration. However, preserving cultural heritage should include the preservation of the acoustical heritage as well. This paper presents CAHRISMA – 'The Conservation of Acoustical Heritage by the Revival and Identification of Sinan's Mosques' Acoustics', a research project carried on within the Fifth Framework INCO-MED Programme of the European Commission. The main objectives of this research are identification, revival and conservation of architectural heritage in a new way. Objective and subjective evaluations and audio-visual reconstruction of Sinan's Mosques and Byzantine Churches in 3D virtual environments are the basic approaches of the project. The main results were virtual restoration, virtual conservation, and determination of different significant acoustical effects.

Introduction

In some spaces such as concert-opera halls and religious buildings, acoustical perception is as essential as and sometimes more important than visual perception. Mosques and churches are among these rare buildings that affect human perception almost equally from acoustical and visual points of view. Unfortunately, conservation and restoration of the architectural heritage have been limited to its material fabric until now. Preserving architectural heritage should include preserving the acoustical heritage, especially for spaces of acoustical importance.

CAHRISMA, *'The Conservation of Acoustical Heritage by the Revival and Identification of Sinan's Mosques' Acoustics',* an interdisciplinary research project carried on within the EC Fifth Framework INCO MED Programme, will provide one of the pioneering products in this field. CAHRISMA is a three-year project, started in February, 2000. The participants of the project are Yildiz Technical University-YTU (Turkey), Technical University of Denmark-DTU (Denmark), Universita degli Studi di Ferrara-UNIFE (Italy), École Polytechnique Fédérale de Lausanne-EPFL (Switzerland), University of Geneva-UNIGE (Switzerland), AEDIFICE (France) and University of Malta-UOM (Malta).

The main objective of the CAHRISMA project is to develop the concept of 'Hybrid Architectural Heritage', which is a new way of identification that covers acoustical as well as visual characteristics. It states that, for spaces having acoustical importance, the architectural heritage concept should be upgraded to cover acoustical and visual properties (KARABIBER, 2000).

The basic goals of the CAHRISMA project are identification, revival and conservation of the Hybrid Architectural Heritage (visual + acoustical heritages) in a real time virtual environment. Sinan's Mosques and Byzantine Churches, which are worship spaces well known for their good acoustical qualities, have been chosen as the buildings to be utilised for the realisation of the mentioned goals.

Methodology of the project

Advanced interdisciplinary and trans-disciplinary features should be used in the identification and conservation of the 'Hybrid Architectural Heritage'. A methodology that will have apparent benefits both in identification and conservation fields has been developed in order to transfer the 'Hybrid Architectural Heritage' into the virtual environment. This methodology covers the combination of visual and acoustical features of the architectural spaces in interactive 3D virtual environments. Through the utilisation of this methodology in situations where architectural conservation and restoration are not available, virtual conservation and restoration will be provided. The methodology of the project consists of the following steps:

1. Acoustical identification and evaluation.
   - Objective identification and evaluation (measurements, calculations).
   - Subjective identification and evaluation (psychoacoustical surveys).
2. Creation of the Virtual Environment.
   - Visual simulation (simulation of spaces, simulation of people).
   - Acoustical simulation.
   - Combined 3D real time simulation with virtual people.
3. Evaluation.
   - Examination of the specific acoustical properties of selected worship spaces.

[1] Sinan is a famous Turkish architect of the 16th century. He has a place in the history of architecture as a stylistic innovator. He designed more than 450 buildings, of which 80 were mosques.

- Assessment of the psycho-acoustical characteristics of these worship spaces.
- Determination of the optimum acoustical conditions for mosques.
- Conservation and restoration of the architectural heritage of selected monuments (acoustical and visual) in a virtual environment.

The flow chart of the project designed according to this methodology is shown in Figure 1.

Work carried out on the project

After the examination of the bibliography, the worship spaces to be worked on in the project were selected. Table 1 shows the selected mosques and churches.

In order to create the basic database for the research project architectural designs, data on the acoustical (AKNESIL, 2001) and visual properties of surface materials and data on religious acoustical activities have been collected and monitored. The alterations of visual and acoustical importance occurring with respect to time (11th century for churches and 16th century for mosques) were determined in order to create the database for the virtual restitution of the selected worship spaces.

For the acoustical identification of the spaces, objective means such as measurements and calculations and subjective means such as psycho-acoustical surveys have been planned. Room acoustic the measurements were carried out basically following the methodologies of ISO 3382. Two teams executed the measurements in order to obtain comparative data. Measurements were taken to determine the realistic usage of the spaces. Impulse responses obtained from each measurable combination of source and receiver position provided data for monaural and binaural analyses of the sound field (PRODI, 2001). Analysis of the data is almost complete.

The measurement of the acoustical properties of the interior materials was among the tasks. Floors which are covered with carpets have a special importance in the sound field of mosques. Therefore, a model was produced and tested in a reverberation chamber to obtain the absorption coefficients (MARSILIO, 2001). To find out the effect of the dome, a scale model was made, measurements taken, and results evaluated.

To characterise the acoustic signals delivered inside worship places, solo and choral pieces of Islamic and Byzantine vocal music were recorded in an anechoic chamber and in real spaces (Kadirga Sokullu Mosque, Süleymaniye Mosque and St. Irene Church). These recordings are used as a database for auralisations, subjective tests and assessment of signals delivered in mosques and churches.

Acoustical simulations were carried out by modelling the six worship places in the room acoustic simulation programme ***Odeon*** (WEITZE, 2001). The findings derived from the simulations were compared with the measured results. Auralisation[2] was another important task which depended on simulation. Auralisations are to be used in two ways: to be included in visual simulations in order to create a realistic environment and to be used in subjective tests. Using the anechoic recordings, auralisations of the places were carried

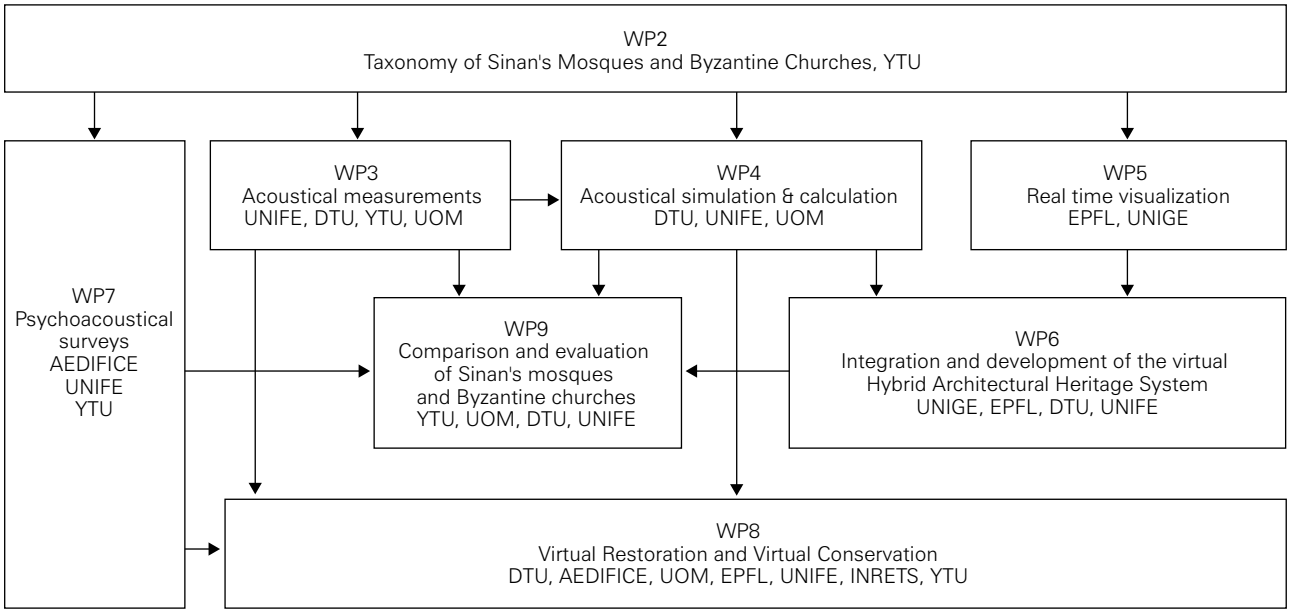

Figure 1. Flow chart of the project.

Table 1. Selected worship spaces.

Name	Location	Date	Architect	Patronage	Approx. volume* (m^3)	Useful area (m^2)	Max. number of persons
Selimiye Mosque	Edirne	1568-1575	Master Sinan	Selim II	79 100	1 890	2 630
Kadirga Sokullu Mosque	Istanbul	1572	Master Sinan	Sokullu Mehmet Pasa-Grand vizier	5 700	490	670
Süleymaniye Mosque	Istanbul	1550-1557	Master Sinan	Süleyman the Magnificent	115 000	3 350	4 640
SS Sergius and Bacchus	Istanbul	527-536	Unknown	Justinian	14 900	760	1 530
St Irene	Istanbul	532 740-rebuilt	Unknown	Justinian	36 100	1 550	4 000
St Sophie	Istanbul	532-537	Anthemis Isidoros	Justinian	258 000	7 960	15 910

*The volumes are calculated from the Odeon models by DTU.

out. 56 sound signals were prepared, combining two stimuli (song and speech), two volumes (5,700 and 115,000m^3), seven reverberation times, and two source-receiver positions for the subjective tests.

Visual simulations were restricted to four of the selected places; Kadirga Sokullu Mosque, Süleymaniye Mosque, S.S. Sergius and Bacchus Church and St. Sophie. A work methodology was developed (PAPAGIANNAKIS, 2001). The 3D models of the selected historical monuments were virtually constructed from available architectural drawings and visual data from the recordings by using 3D Max and Photoshop software. Furthermore, the 'Lightscape' software package was utilised in order to enhance the photo-realistic aspect of the 3D reconstructed models of the monuments. The work on the simulation of life inside the mosques is ongoing.

For the subjective evaluation of the worship places, a social survey and laboratory simulation experiments have been planned (VALLET, 2001). The evaluation of the acoustics of the mosques is comprised of three steps: a psycho-social survey of 120 users, to find their spontaneous opinions on the relative importance of acoustics, two sets of 14 interviews with specialists in acoustics so as to get their impressions on registered and auralised sounds and to select the main acoustical parameters of their judgement, and an experiment on a sample of 90 people consisting of three sub-samples, using the 56 auralised sounds. Analysis of the data is completed.

Two different media for presenting acoustical and visual environments are proposed: one is a semi-interactive CD-ROM based on a high quality hybrid presentation platform, the other is for broader dissemination on the Internet, where users can walk through the monuments by downloading a VRML model. The first media will enable the presentation of very high quality results to the academic community, whereas the other will permit anyone who is interested to access the 'medium quality' 3D models. Work on the presentation (scenario) of the virtual acoustical conservation has also been started.

The architectural, aural, acoustical and visual data collection of the CAHRISMA project has been completed. The acoustical and visual simulations, which include virtual interactive life so as to create more realistic visual environments, are almost completed. Analyses and assessments of specific acoustical properties of ancient spaces other than mosques and churches are ongoing.

Main findings and results

One of the most important works of the study is the development of several methodologies regarding different tasks of the project. The data collection methodology of architectural heritage for virtualisation, methodologies used on acoustical and visual virtualisations, methodology for scale modellings of domed spaces and methodology for psycho-

acoustics evaluation of the mosques can be cited among these.

A proposal for the optimum reverberation time, to be used in the construction of the new mosques with good acoustics, has been made. Effects of domes, which are generally accepted as harmful constructions for acoustics, are investigated and it has been shown that due to the appropriate architectural proportions in Sinan's mosques and Byzantine churches no harmful effect occurs.

The three churches investigated in the CAHRISMA project have been used for different purposes (such as church, mosque, museum) through their existence, and have had different materials and furnishings. Different acoustical models have been made in order to represent the different configurations and acoustic environments these variables could cause. It is now possible to hear how the rooms might have sounded some 15 centuries ago (WEITZE, 2002).

Visual virtualisations of Kadirga Sokullu Mosque and S.S. Sergius and Bacchus Church are completed. The current state of visual virtual restitution covers the modelling of the whole site of St. Sophie's, both for the Byzantine and Islamic periods, and the texturing for both real-time and non real-time photo-realistic simulations concerning the sixteenth century restitution (FONI, 2002). A virtual crowd was introduced into the real-time 3D reconstruction of a complex heritage edifice to increase the realism of the reconstructed scene. A virtual population of worshippers performing morning Namaz prayer inside a virtual mosque was also created (ULINCY, 2002). Figure 2 and 3 show Sokullu Mosque with virtual humans.

Figure 2. Crowd enters Sokullu mosque (ULINCY, 2002).

Figure 3. Crowd performing praying in the Sokullu Mosque (ULINCY, 2002).

Conclusions

The main objective of this research has been the identification, revival and conservation of architectural heritage from a new perspective. Objective and subjective evaluations and audio-visual reconstruction of Sinan's Mosques and Byzantine Churches in real-time 3D virtual environments have been the basic approaches of the project. Virtual restoration, virtual conservation, and the determination of different significant acoustical effects are to be the main results. By means of this wide frame research, conceptual and practical innovations will be created in the fields of acoustics, architecture and simulation technologies.

The selected worship spaces are undoubtedly the best examples of their type and their era. The conservation of those religious edifices in a virtual environment will be a great step forward and a perfect example for the innovation of conservation and restitution methods.

[2] Auralisation is a term introduced to be used in analogy with visualisation to describe rendering audible (imaginary) sound fields. Several modelling methods are available in architectural acoustics for this purpose. Together with new hardware implementations of signal processing routines, auralisation forms the basis of a powerful new technology for room simulation and aural event generation (KLEINER, 1993).

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Zerhan Karabiber

Building Physics Department,
Faculty of Architecture, Yildiz Technical University
Besiktas, 34349 Istanbul, Turkey.
e-mail: karabi@yildiz.edu.tr

Having graduated in building physics at the Architectural Faculty of Yildiz Technical University, Istanbul, Turkey, in 1981, she joined the Building Physics Department in the same year. She received her doctorate there in 1988, and became full professor in 2001. Z. Karabiber is one of the founders of the Turkish Acoustical Society, of which she has been the general secretary since 1996. Although having a large basis in fields related to building physics, her specific field has been architectural acoustics. Currently, her main research activities are in the acoustics of old Turkish mosques, and classroom acoustics.