A RESEARCH PROJECT IN THE INTERSECTION OF ARCHITECTURAL CONSERVATION AND VIRTUAL REALITY: CAHRISMA

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KEY WORDS: Heritage, Virtualisation, Architecture, Conservation

ABSTRACT:

CAHRISMA - "Conservation of the Acoustical Heritage by the Revival and Identification of Sinan's Mosque's Acoustics", research project carried on within the Fifth Framework INCO-MED Programme of the European Commission, is designed by the goal to innovate the acoustical heritage concept in the field of architectural conservation. 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 interactive 3D virtual environments are the basic approaches of the project. Virtual restoration, virtual conservation, and determination of different significant acoustical effects are the main results. In this paper CAHRISMA Project which takes place in the intersection of architectural conservation and virtual reality is presented.

1. INTRODUCTION

Conservation of the cultural heritage covers all sorts of efforts to protect and transfer the historical document in its all authenticity to future. That' s why, conservation of the architectural heritage includes the presentation of the artwork to the society by all its different dimensions and past usages, besides the protection. There are three phases of the architectural work. First phase is the construction and utilization of the building for an identified function where every kind of hardware and elements are present to serve the function. The second phase starts soon after the first one and lasts during the whole life of the building. The rate of the alterations that an architectural work sustains throughout the second phase differs upon cultural and social environment. However it is not easy to expose this historic stratification on a protected and utilized building. The recent situation of the building where we met and interfere to the architectural heritage depending on the conservation concepts and principals is the third phase. The point of view at the third phase is different; the building is more then a simple coverage of human activities, it is an historical document and a mirror to the social and cultural development process.

The aim of the CAHRISMA Research Project is the presentation of the architectural heritage to the community beside its physical being that we met at the third phase. To illustrate the different layers and stratifications of the architectural heritage has always been a difficult task because of the concerns about possible harms on the physical structure of the work. It is not always possible to illuminate all of these features by drawings and texts and moreover this method is generally only comprehensible by experts. By the developments of computer technology, it is now possible to recreate environments belonging to one of the different periods of the building in virtual reality and present it together with the artificial environment visualising the cultural features of the related period. Till nowadays these works were limited to visual perception, however it is possible to recreate different environments effecting human' s various perceptions.

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).

Basic goals of the CAHRISMA Project are identification, revival, and conservation of the combined architectural heritage (visual + acoustical heritages) in a real time virtual environment, like one Time Machine. This project supported by European Commission will open new dimensions having boundaries difficult to dream within the architectural conservation concept.

For the realisation of the mentioned goals, three Sinan's mosques from 16^{th} Century; Kadirga Sokullu, Süleymaniye, Selimiye and three Byzantine churches from 11^{th} Century, SS.Sergius and Bachus, Hagia Eirene (St. Irene), Hagia Sophia (St. Sophie) are selected as the worship spaces to work on at the project. These worship spaces are well known for their good acoustical qualities.

This paper aims to present the CAHRISMA Project which takes place in the intersection of architectural conservation and virtual reality, spotting that the acoustically supported virtual restitutions would be one of the major steps to transport the architectural heritage to the future.

2. METHODOLOGY OF THE PROJECT

Advanced interdisciplinary and trans-disciplinary features should be used in the identification and conservation of the 'Combined Architectural Heritage'. A methodology that will have apparent benefits both in identification and conservation fields has been developed in order to transfer the 'Combined

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 utilization 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. Identification and Evaluation
   - Objective identification and evaluation (measurements, calculations)
   - Subjective identification and evaluation (psycho-acoustical 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
   - 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

3. 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 projects, data on the acoustical [1] and visual properties of surface materials and data on religious acoustical activities have been collected and monitored. The alterations having visual and acoustical importance occurring with respect to time were determined in order to create the data base 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 measurements were carried out basically following 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 analysis of the sound field [2]. 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 [3]. To find out the effect of the dome, a scaled 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 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 program Odeon [4]. The findings derived from the simulations were compared with the measured results. Auralisation 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 out. 56 sound signals were prepared, combining two stimuli (song and speech), two volumes (5700 m^3 and 115 000 m^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 [5]. 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 utilized 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 [6]. 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 judgment, 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. A scenario is designed to present the virtual acoustical conservation.

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

4. ARCHITECTURAL HERITAGE DATA COLLECTION FOR VIRTUALISATION

Appropriate and accurate methodology for collecting data required for virtual heritage is an important issue. The realism of the virtual reconstruction greatly relies on the quality of the data collected. Therefore, a detailed database covering numerous subjects have to be formed in order to recreate an historical building together with virtual humans and activities realised within this building in virtual environment [7]. On the other hand, the extent of the scope and the details are directly related to the building function and the aimed precision. In this section the methodology developed for creating the database for acoustical and visual virtualisation of CAHRISMA Project buildings will be presented and exemplified.

4.1 Methodology of Data Collection

Detailed data on the acoustical and visual properties of the ancient spaces are required for the virtualisation. Different types of data, grouped as architectural, functional, acoustical and visual, have to be gathered in order to create the basic database for the virtual conservation and restoration of the buildings. Basic steps of the data collection are designed as follows:

Architectural data
Three basic investigations are required in order to obtain a complete architectural data:

- Structural and architectural specifications of the buildings
- Visual properties of interiors and exteriors
- Furnishing

Data related with functional activities
Activities related to the building function have also to be determined in order to realise the visualisation. People's clothing should be considered according to the era that the visualisation would be realised.

Acoustical data
Acoustic properties of

- Rooms
- Materials used in indoors
- Activities (speech/ music)

should be determined**.**

Lighting and colour data
For the lighting and colour properties, determination of

- Indoor's lighting syste ms
- Natural and artificial illuminances
- External daylight illumination levels
- Ancient luminary properties
- Indoor material light reflectance and colours

should be realised.

Steps of the mentioned methodology will be exemplified in the following sections, based on the Project.

4.2 Collection of the Architectural Data

While trying to recreate historical edifices in virtual environment, it is important to expose the ancient and the recent situations of these buildings. For the buildings investigated in the CAHRISMA Project, it has been detected that some modifications were occurred due to different reasons such as renovations, restorations and functional changes through the time. Therefore the period that will be presented in the virtualisation has to be determined. 16^{th} Century has been chosen for the virtual restitution of Sinan's mosques because this was the era they have been built. Almost no great changes have been occurred in the religious rituals and the objects used on Islamic prayer throughout the time. At 1054 Roman Church and Byzantine Patriarch excommunicated each other causing their definite separation on the liturgical initial, spaces and use of objects, so the 11^{th} Century has been accepted as the era for virtual restitution of the selected Byzantine churches [8].

In order to expose the structural and architectural specifications of the buildings;

-Plans and sections were collected.
-Modifications occurred in time were determined.
-Collected data were compared with the recent situation by checking measures in situ where necessary.

In Figure 1, an example showing the alterations in one of the edifices- St. Sophie (Haghia Sophia) Church- is shown [9]. For the visual properties of the interiors, drawings and photos were examined. Furnishing of the ancient and the recent situation was also determined. The data collected under this topic is used as the database of the visual and acoustical virtual reconstruction of the buildings.

4.3 Collection and Presentation of the Acoustical Data

As mentioned in Section 2, acoustical data covers rooms, materials used in indoors and activities. Room acoustical properties can be determined by measurements and/or calculations [1, 3, 4]. In the CAHRISMA Project both have been realised and crosschecked to show the accuracy of the findings. Measurements were realised by three teams (UNIFE, DTU and YTU) according to ISO standards and calculations were done by using Odeon and other softwares [2, 4, 8, 10].

Each space has been elaborated carefully in-situ and surfaces having different materials in terms of acoustics are identified. These are shown on coloured drawings (plans and sections) and used to estimate the sound absorption properties of the indoor surface materials. An example is given in Figure 2 [1, 11]. Sound absorption coefficients of the materials such as carpets, tiles and stones are measured in laboratory. The alterations occurred in time are determined from the available literature in order to use in the virtual restitutions.

According to the activities realised in the buildings, acoustical activities such as speech and music have to be determined. In the CAHRISMA Project, sounds related to religious activities such as sermons and prayers are specified and recordings in situ during ceremonies as well as recordings in anechoic chambers are realised.
-Findings of these works were used in the auralisations created for the virtual environment.

4.4 Collection and Presentation of the Lighting and Colour Data

In order to create a realistic virtual environment, lighting systems and colour of the materials should be determined precisely. Natural and artificial lighting systems of the CAHRISMA Project's edifices were examined in situ (YTU).

Natural and artificial illuminances on the internal surfaces are measured. Results are presented on the plans. An example is given in Figure 3 [9].

External daylight illumination levels depending on the average sky conditions and statistical meteorological data of the region were used to obtain realistic internal visual virtualisation. Luminaire location plans are determined in situ and luminaire light specifications are measured in laboratory [9]. Data on the inner surfaces colour and light reflectance properties are measured in situ by using high quality colorimeter [10].

5. CONCLUSION

The main objectives of the CAHRISMA research project are 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 are 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.

On the other hand, 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 and a perfect example to the innovation of conservation and restitution methods.

In the virtualisation, one or several of the topics presented in the text may have a special importance depending on the function of the building; therefore the data collection should be rearranged according to the building function.

ACKNOWLEDGEMENTS

CAHRISMA Research Project (ICA3-1999-00007) is being supported by the European Commission, within the 'Confirming of International Role of Community Research – INCO MED' program of the Fifth Framework.

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Table 1. Selected worship spaces

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

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

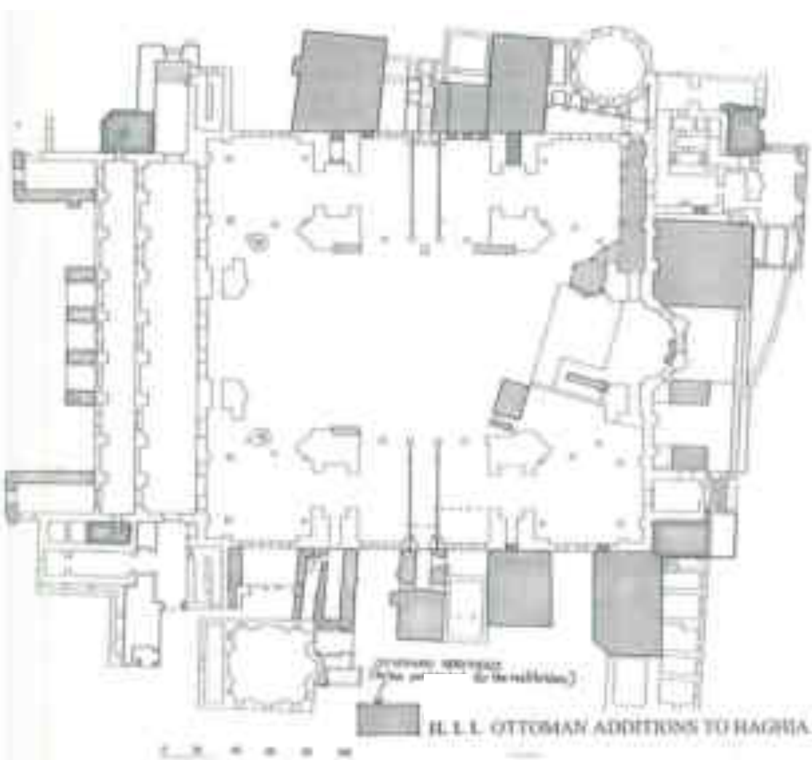

Figure 1. Ground floor plan of Saint Sophie showing additions from the Ottoman time

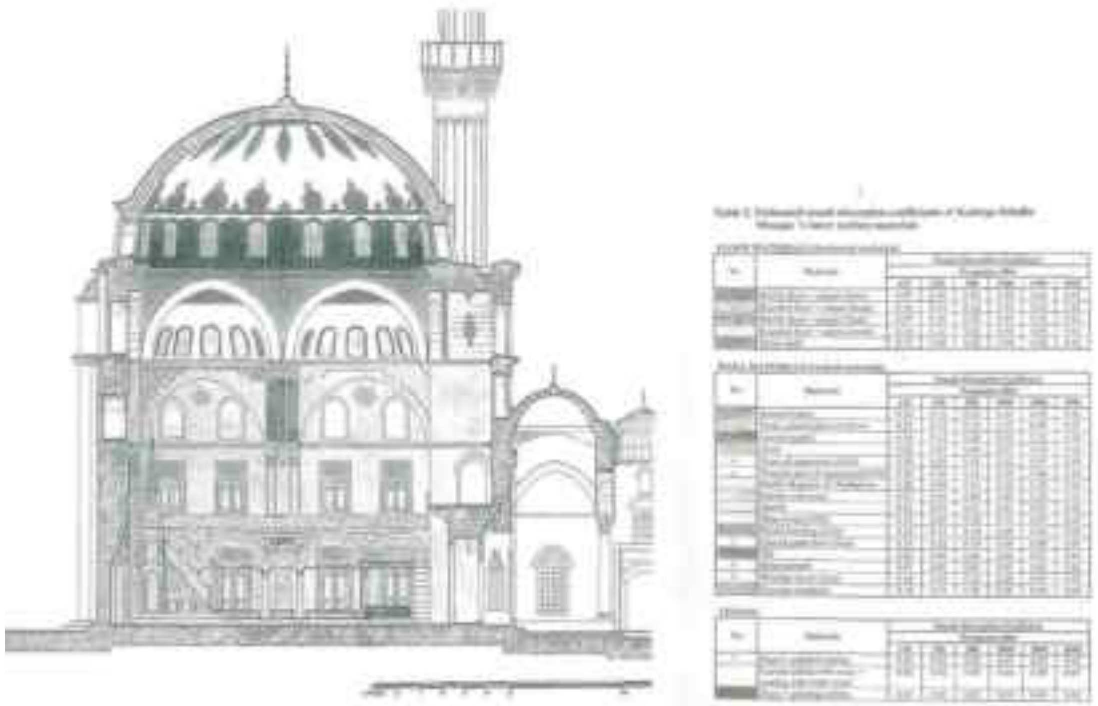

Figure 2. Section of the Sokullu Mosque and its inner surface material's absorption coefficients in grey scale

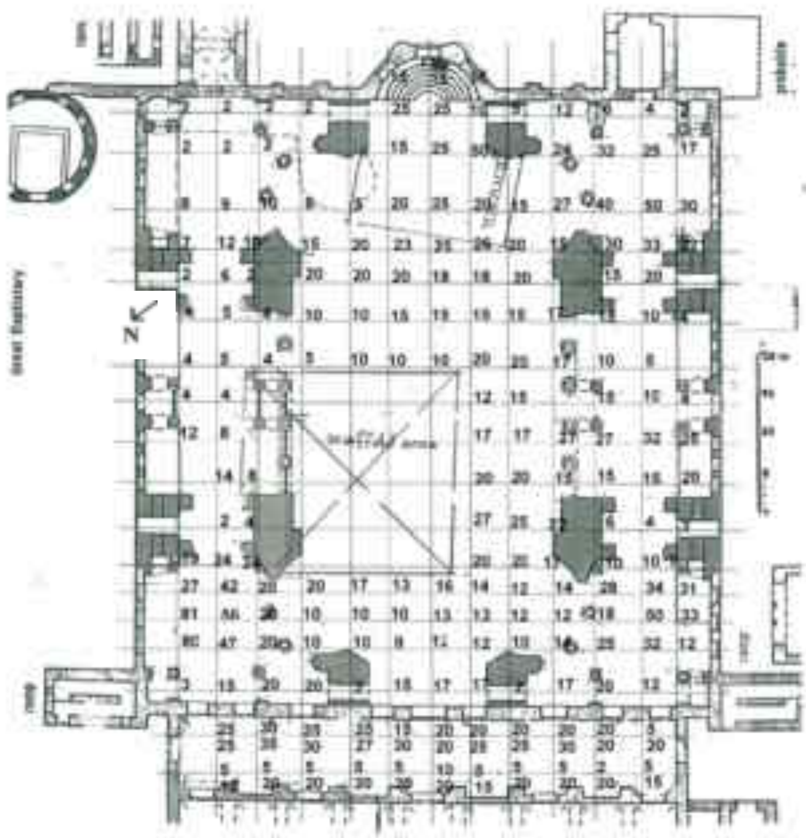

Figure 3. Measured illuminance on the ground floor of St. Sophie (9 October 2000; h: 10.15-12.15)