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THE GENERATION AND 3 DIMENSIONAL DISPLAY OF AUDITORIUM FORMS BY MEANS OF THE WWW

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Abstract

Research has established the factors which contribute to good acoustical conditions in auditoria. The challenge now is to ensure that these research findings inform the design strategies of practising architects. The underlying premise of this paper is that good acoustical design is a generator of architectural form for auditoria and that architects relate best to visual information. Good acoustical design can only be enhanced if architects can readily perceive the correlation between the acoustical and spatial qualities of prospective auditoria. A set of design rules based upon acoustical principles is presented by means of a simple interface which leads to an outline specification for an auditorium which is used to generate 3D models of a space in a virtual environment. The user is then able to investigate the nature of the space from the perspectives of both performers and audience. In future work it is planned that auditory experiences will also be possible.

INTRODUCTION

This paper is concerned with the use of 3D models of auditoria in room acoustics tutorials delivered via the WWW. It builds upon earlier work by the author's in which both 2D and 3D representations of auditoria were employed [1,2]. Research has established the factors which contribute to good acoustical conditions in auditoria [3-5]. However, the underlying hypothesis of the work described in this paper is that the architect's preferred method of relating to an auditorium is visual and that acoustics is secondary. Architects will design a space primarily from the point of view of its visual quality and seek to make the acoustics work within the limitations imposed by their earlier decisions. This explains the acoustically challenging forms of many

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auditoria. Good acoustical design can only be achieved if architects can readily perceive the correlation between the acoustic and spatial qualities of prospective auditoria. The questions that we seek to address are:

- Can we integrate the visual and the acoustical?
- Can we generate examples of spaces which are conducive to good acoustics and enable the architects to experience those spaces with a view to correlating the visual to the acoustical characteristics?

The approach adopted aims to make it possible for the designer to visualise the spatial qualities of an auditorium designed on the basis of good acoustical principles from the point of view of performers and audience. As the objective was to make the tutorial easily accessible to students, a web based approach has been employed. Two requirements had to be satisfied. The first was the provision of 3D models of auditoria designed according to good acoustical principles and the second was to display these models in an interactive form by means of the World Wide Web.

ACOUSTICS AND GEOMETRICAL FORM

In designing auditoria to achieve good acoustical conditions, the geometrical form of the space is of paramount importance. It can be argued that the requirement to achieve good acoustical conditions should be the principle determinant of the geometrical form. It follows that acoustically well designed auditoria will share many common features and it is these that students should learn to recognise as being a fundamental requirement for successful acoustical design.

The first characteristic is a clear line of sight between performers and all members of the audience. The reciprocal relationship between performer and audience is one that few students comprehend. It would be a worthwhile experience for them to “sit” in their auditorium and look towards the stage and also for them to view the audience from the stage.

The second characteristic relates to the extent and proportions of the audience area relative to that of the stage platform. Ideally, a performer should be able to communicate visually with all members of the audience. This is not possible if the seating area is too wide, when a significant proportion of the audience will, at best, be only in the peripheral visual field of the performer. If the auditorium is too long then not only does visual contact become impossible for audience members at the rear of the hall, but the loudness of the direct sound may suffer badly.

The third characteristic is the ceiling height. Many students produce designs with oppressively low ceilings, especially above the seats at the rear of the hall. This fault invariably occurs alongside that of the inadequate seating rake and poor sight lines.

A large auditorium will invariably need the provision of substantial areas of highly reflecting surfaces orientated to direct sound into the seating area. This element will have a very considerable impact on the visual nature of the space. It would be valuable for students to “stand” in the position of the performer where it is very easy to identify these surfaces and to visualise how the sound made by a performer will be re-directed.

All of the above features can be experienced interactively with 3D models in virtual environments.

DEVELOPMENT OF THE 3D MODELS

The first requirement of this work was the ability to generate models of auditoria designed according to good acoustical principles very rapidly. This part of the work built upon earlier experience in the development of an expert system for advising architects on the design of auditoria [6]. The system consisted of three modules which replicate stages in the design process. The first module, PRADA (Preliminary Room Acoustic Design Advisor), provides preliminary acoustic design advice and was constructed using the multiple rule base and object frame functions of the LEONARDO expert system shell. The second module, AFGEN (Acoustical Form Generator), takes this advice and produces a basic geometrical form (a 3D computer model) which the designer can amend if desired. The third module, RASTO (Room Acoustic Treatment Optimiser), enables the acoustical treatments applied to the internal surfaces to be optimised to achieve the required acoustical characteristics.

The basic concept of an expert system is that the user supplies facts or other information to the system and receives expert advice depending on the knowledge contained in the knowledge-base. Expert systems differ from procedural software in that the knowledge component is separated from the processing part or inference engine [7]. The knowledge is frequently embedded in a number of rules of the form:

IF *Antecedent* THEN *Consequent*.

An example of a simple rule might be as follows:

IF *Function* is Music
then
PreferredPlanForms are
Rectangular
FacetedFan

A rule can have both multiple antecedents and multiple consequents. Figure 1 shows the way in which antecedents and consequents are developed in PRADA. The initial antecedents are *Function*, *Capacity* and *Status*. It can be seen that consequents become antecedents in later stages of the process. A given antecedent will typically give rise to a consequent which might offer 4 options. As shown in Figure 1, there are 10 antecedents and thus there are approximately 10^4 possible specifications. These could be implemented by means of a rule per specification but this would be very inefficient. However, PRADA was developed using the LEONARDO expert system shell which offers two strategies for reducing the number of rules. The first is the use of rule sets which enables knowledge relevant to some sub-goal to be related explicitly to that sub-goal. The second is the use of object frames with multiple level inheritance. Both were employed in the development of PRADA.

Although PRADA functioned well it suffered from being developed in LEONARDO which was rather elderly MSDOS base software with a poor user interface. However, one outcome of the work on PRADA was the recognition that the progress through the rule sets could be made in a sequential manner consisting of a set of well defined steps. This obviates the need for the full power of an expert system shell incorporating such features as forward and backward chaining. Therefore, in this work the basic rule sets developed for PRADA were re-written in Java which enabled more user friendly features, such as an interface with choice boxes, to be employed. The Java language also fulfilled the requirement to run the software via the WWW.

	CONSEQUENTS									
Antecedents	Geometry	Levels	Size	Rake	Stage	Seating blocks	Plan area	Height	Reflectors	
Function	***	**	*		*	**		***	***	
Capacity	**	***	***	*		***	***	***	***	
Status	*	*				*	**			
Geometry				*	*					
Levels			**	***	***		**	*		
Size				***		**				
Rake					**			*		
Stage										
Seating block							**			
Area plan								***	***	
Height										

Figure 1 –Showing relationships between antecedents and consequents

The first stage of the tutorial involves the student inputting data in response to a series of questions. At the end of the process sufficient information can be provided from the system to enable the automatic creation of a 3D model of an auditorium.

VISUALISATION OF THE 3D MODELS

There are a number of possible approaches to the development of 3D models for display via the WWW including Java 3D, OpenGL, Direct3D, VRML and X3D. Initial work was carried out using Java 3D which includes the most essential features found in the other API's. However, because it is based on Java, it offers higher level programming constructs [8]. It also differs in the simplicity with which it integrates with other programming facilities. For example, to display a window of Java3D content in a typical Java program simply requires the creation of a frame and the addition of a 3D canvas. Registration for mouse and keyboard input is then all that is needed as the basis for interaction.

Other options which are being investigated are the use of X3D [9,10] and Direct3D [11], the latter has been employed by Drumm using the C# programming language and the .net platform.

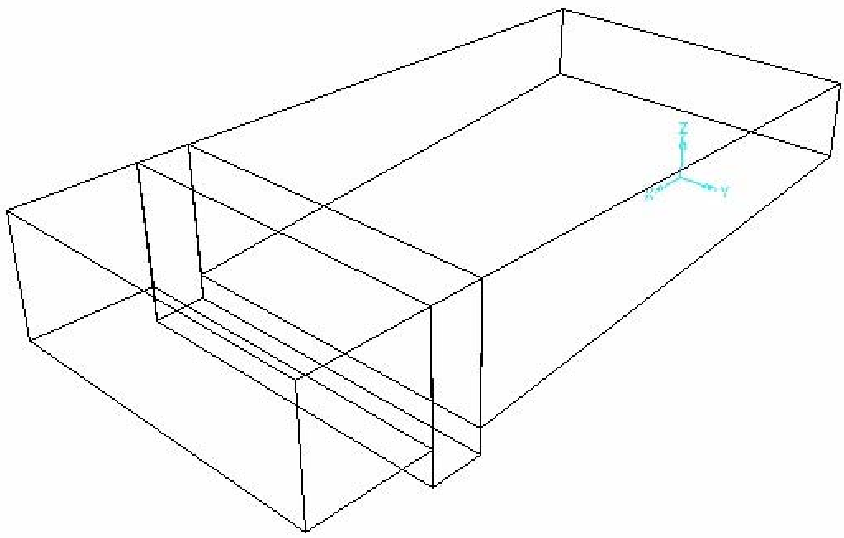

Figure 2 – Showing basic configuration of a simple auditorium

In a virtual world such as produced using the options listed above, the objects are known as shapes which consist of two pieces; geometry and appearance. In Java3D, for example, the basic node for shape data is Shape3D which is a container for Geometry and Appearance node components. The basic kinds of geometry are created using GeometryArray node components.

In earlier work the development of a program called AFGEN for the rapid generation of 3D models for use in RAYNOISE has been described [6]. In RAYNOISE models of auditoria are built up of plane surfaces called elements which are defined by points called nodes. AFGEN generates nodes and elements using basic geometrical data (overall length, widths, heights, etc.) supplied by PRADA.

In the context of this work, which involves the creation of 3D models consisting of an arrangement of simple rectangular plane surfaces, the QuadArray subclass of the GeometryArray class corresponds to the elements of RAYNOISE. This program has been used as the basis of a new program to generate Java 3D models called JAMODGEN (Java Model Generator) [6]. This enables a range of 3D models to be obtained very quickly and enhances the usefulness of the tutorial.

Figure 2 shows the form of a basic auditorium. The co-ordinates of the nodes can be calculated from input of a few key dimensions including length of seating area, width of seating area at both the front rear of the hall (thus allowing for fan shaped plan forms), seating rake, stage height, stage depth, forestage distance and overall ceiling height. These dimensions can be obtained from the first stage or they can be input directly by a user.

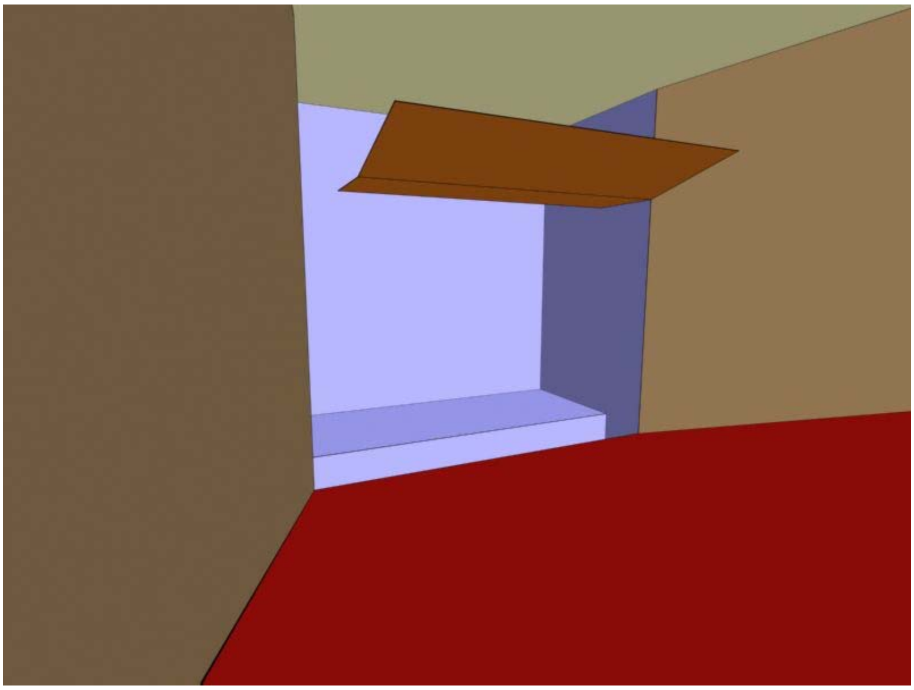

Figure 3 – Showing view of stage from audience location at the rear of the auditorium.

As the objective was to enable students to experience the interior of these auditoria, it was necessary to offer the choice of suitable viewing points (camera positions). A completely free choice of viewpoints, although possible in principle, was not allowed as precise movement around the inside of the model requires the development of some skill thus a limited number of fixed viewpoints were made available. The concept of the reciprocal relationship between performers an audience has been mentioned above. It was seen as important to enable the student to switch between identifiable viewpoints on the stage and identifiable viewpoints in the audience area. Figure 3 shows an interior view of a simple auditorium model from a viewpoint at the rear of the hall.

DISCUSSION

It has proved possible to develop a system which enable the rapid generation of simple acoustical forms for display in a virtual environment via the WWW. However, the 3D experience is affected by the characteristics of the viewpoint employed. These can be likened to a photographic camera with a choice of lenses. The view from a given point can be similar to that which would be taken by a camera using a standard, a wide angle or a telephoto lens. Each lens type can be used to obtain specific effects or to bring out particular points but none truly reproduces the visual experience that would be experienced in the real world.

A number of alternative application of the techniques described in this paper, have been identified. Students could be asked to provide appropriate dimensions for an auditorium suitable for speech or music and this design would be then be rated using a simple numerical scheme based upon the rules used in the mini expert system. Having been presented with an overall rating, students could then be invited to explore the 3D model of their designs and asked to comment on its strengths and weaknesses. Modifications could then be made to the dimensions if necessary to improve the rating. Students could also be presented with models of good and bad auditoria and asked to experience their spatial qualities and to try to identify what are the relevant factors that differentiate them.

SUMMARY

This paper has described a tutorial aimed at students of architecture with the objective of developing their understanding of the geometric requirements of good acoustical design. A web based mini expert system has been developed to enable the geometric specification of a 3D model to be obtained from the input of basic data regarding room function, capacity and status. This specification can then be used for the automatic generation of a basic 3D computer model and the student is able to experience this virtual auditorium and, in particular, to experience its spatial quality from the point of view of both performers and members of the audience. At some point in the future it may be possible to incorporate auralization of the sound field and thus enable students to gain an even richer experience. Some preliminary work in this area has been reported by Drumm[11] using Direct3D and the C# programming language.

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