AN ENGINE FOR REAL-TIME AUDIOVISUAL RENDERING IN THE BUILDING DESIGN PROCESS

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Abstract

The gathering of information or data in shared models is becoming more frequent in the course of planning new buildings and environments. Three-dimensional visualizations of such models are often utilized as means for verifying the final design proposal. Simulations offer opportunities for an overall impression of environments prior to construction. They also support and improve communication between disciplines, allowing design decisions to be evaluated on a perceptual basis. TyrEngine is an application built to enable real-time visualizations based on a computer game engine. It is currently a part of Tyréns visualization toolset and can be freely distributed with no additional licence costs. Aimed specifically to provide aid in the planning process, visuals can be generated from a variety of geometrical input formats, such as those common to CAD. In this paper the addition of acoustic information through auralization is discussed. In addition, results are presented from initial tests to acoustically couple motion utilizing the engine's inherent features. With evolving techniques for performing auralization, it has become a more integrated phase in the acoustic design of environments. Acoustic simulations are often utilized when existing building regulations do not stipulate design criteria or as means to determine such specific to a project. Hybrid simulations as proposed in this paper have the potential to widen the discussion on complex spatial features and aid discussions on quality of built environments.

1. Introduction

1.1 Shared platforms – BIM

In the design process of new buildings the architectural, mechanical, structural, and acoustical design needs to come together as a whole. The final design proposal, with contributions from all members of the designing team, need first and foremost to ensure overall functionality associated to the purpose of the facility. The proposal should also strive towards providing a quality of the space experienced by the building's future occupants. Communication of design decisions as they progress has been alleviated through shared planning platforms and the introduction of BIM, Building Information Modelling. Overcoming the introduction period working with BIM, it offers many possibilities. BIM enables sophisticated model structures, where all disciplines have access and work towards the same models. As data is stored and shared in the same place, information retrieval is made easier.

1.2 Simulation in building design

As a mean of verification in the final planning stages, BIM models can be visualized through high quality visual rendering. Thus allowing the project group and other interested parties to evaluate and verify the building based on visual sensory input, prior to construction.
At the same time, high quality auditory rendering or auralization of the building and events to be taken place there, are becoming a more common stage of the planning process. It is for auralization purposes possible to build the acoustic model from the project's three dimensional CAD-model, often the format of projects using BIM. The acoustic model can later be used to obtain calculated room acoustic parameters as well as audio for performing auralization. Auralization reproduces three dimensional auditory environments including events to be taken place such as communication between occupants, motion of people, operation of machines etc., including the spatial characteristics in transmitting the sound of these events in the room. Auralizations are often utilized at an early planning stage, as means for deciding acoustic characteristics, and at a later planning stage as means for verification. In situations where standardized acoustic criteria according to building regulations cannot be applied, auralizations become a crucial instrument for the acoustician to communicate design strategies to other parties of the planning process. Auralizations are adopted for planning a variety of built environments such as offices, schools, atriums, auditoriums, etc.

Both methods for performing high-quality visualizations as well as auralizations have evolved rapidly during recent years due to, perhaps most importantly, developments on computational efficiency. From these advances and with the shared platform format of BIM, the combination of high-quality visualization and auralization of environments within the planning process, can be discussed. A hybrid approach has the potential of enabling more complex quality assessments providing a multi-sensory experience. Design decisions can be assessed perceptually at an early stage avoiding exceeding costs of reconstruction after completion.

2. Auralization and visualization techniques

2.1 Room acoustic simulation

Recent years advances in room acoustical prediction and simulation can be seen as following a few main paths. Execution time for predicting spatial sound transmission are being reduced besides improved computational efficiency also as a factor of enhanced algorithms. The accuracy of prediction is developing through the use of hybrid calculation methods, utilizing image source modelling, ray tracing and wave- based techniques. Finally the reproduction of the auditory environment is being considered with the addition of "listener" interaction, in order to enhance the simulation experience.

Modes of interaction may include motion, allowing the listener to move in the space with updated spatial characteristics; alteration of spatial boundaries during simulation [1-2]; and enabling the listener to generate sounds, effectively allowing a direct experience of the acoustical response [3]. To enable such interaction as those mentioned here, some real-time processing is necessary. Thus the decrease in execution time for predicting room transmission is required.

2.2 Visualization through game engines

The scope of this study does not include a full discourse on available technologies for visualizations. Instead focus is given on visualization through game engines. Game engines offer high-quality rendering of visual environments. The use of such platforms has previously been proposed for simulating architectural environments in educational or verification purposes [4-6]. These engines easily imports architectural data sets. Most also offer an extended material directory. Light transmission can be calculated through ray tracing and changed throughout the simulation to correspond to time of day. Game engines offer inherent features suitable for interactive virtual reality applications such as the ability of user-controlled motion. A majority of game engines are open ended, allowing the addition features through customized coding.

2.3 Audiovisual simulation

It is today a more common practice to add visual information when performing auralization. This usually requires access to the architect's visual renderings if not utilizing the very simplified acoustic model as reference. Research on this topic indicates a relevance to provide visual information when performing auralization. Findings related to the sense of *presence* as defined by Ozawa, Ohtake, Suzuki, and Sone as "one has the illusion of being in some place or environment", indicate benefits when simulations contains both auditory and visual information of the space, [7]. Studies on the interaction between visual and auditory sensory input in regards to the experience of both real and simulated environments, suggest that a) such can be expected in both real and virtual rooms, and b) indicates that the fidelity of the virtual environment affects the experience of it. [8]

3. Application requirements

It is the intention within the future of this project to explore possibilities of either carrying out necessary processing for the auralization and visualization within the game engine structure or to couple two separate models through common interfaces. This in order to increase the efficiency of performing necessary operations while keeping costs low. However as a first step, the acoustic transmission calculations and convolution are carried out separately in dedicated acoustic software only later imported into the engine as live audio. Future goals and already reached goals for such an application is presented in the following sections.

3.1 Input data retrieval

To perform simulations in the building planning process, the application needs to handle a variety of geometrical data sets. Data structures such as CAD are most commonly employed with BIM. Both acoustical and light calculation should, for efficiency purposes, stem from the original BIM model of the project. The geometry should be sufficiently detailed for calculation of light transmission however needs simplification for the calculation of acoustic transmission. As wavelengths differ, some room boundaries will be acoustically redundant however visually important. This suggests that two different models should be employed. Coupling of the two should however be made when possible to do so. Material characteristics need to be defined both for sound and light transmission. Ideally databases would be connected, containing relevant data for both light and sound calculations.

3.2 Representation of events, source specification

Events or activities taking place within the simulated environment are acoustically specified as sound sources and represented visually. Activities chosen for simulation should have relevance to the environment. Moving sources require continuously updated acoustical and visual representation.

3.3 Calculation of sound and light transmission

Both sound and light transmission is calculated using ray tracing methods. The room impulse response is predicted using Image source modelling for early reflections and ray-tracing for late energy reflections. For real-time prediction on a personal laptop some statistically based assumptions are necessary for the late part of the sound decay process. However for complex geometries this may not be a satisfactory assumption, nor for non-diffuse sound fields. For a real-time prediction complex acoustical effects such as diffraction cannot be included.

3.4 Interaction

Added interaction should benefit the experience of the simulated environment. Accordingly the following modes of interaction for the initial stages of the application are proposed. Possibility of acoustically and visually connected user-controlled motion. This allows the experience of the space from different positions as well as the transition between rooms. The ability to alter room boundary characteristics with real-time updates of the auralization and visualization would aid in the discussion on design approaches.

3.5 Reproduction

The hybrid simulation should be reproduced in a manner that facilitates the immersive nature of its purpose. Acoustically this means binaural reproduction through headphones or sound field encoding/decoding through methods such as ambisonics. The latter reproduced through a multi-channel loudspeaker system. Virtual reality applications such as the Oculus Rift offer potential for a visually immersive experience. Wearables such as virtual reality systems and headphones will however affect the ability to communicate during simulation. In contrast, ambisonics reproduction along with multiple or single- screened projection require simulation to occur in dedicated presentation rooms. Both reproduction methods will be incorporated at different stages of planning.

4. Application architecture

The underlying software for this study, TyrEngine, is a visualization process/application based on the real-time engine Unreal Engine 4. *Unreal Engine 4, UE4,* is provided by *Epic Games* offering a free licence for use in the field of architectural visualizations.

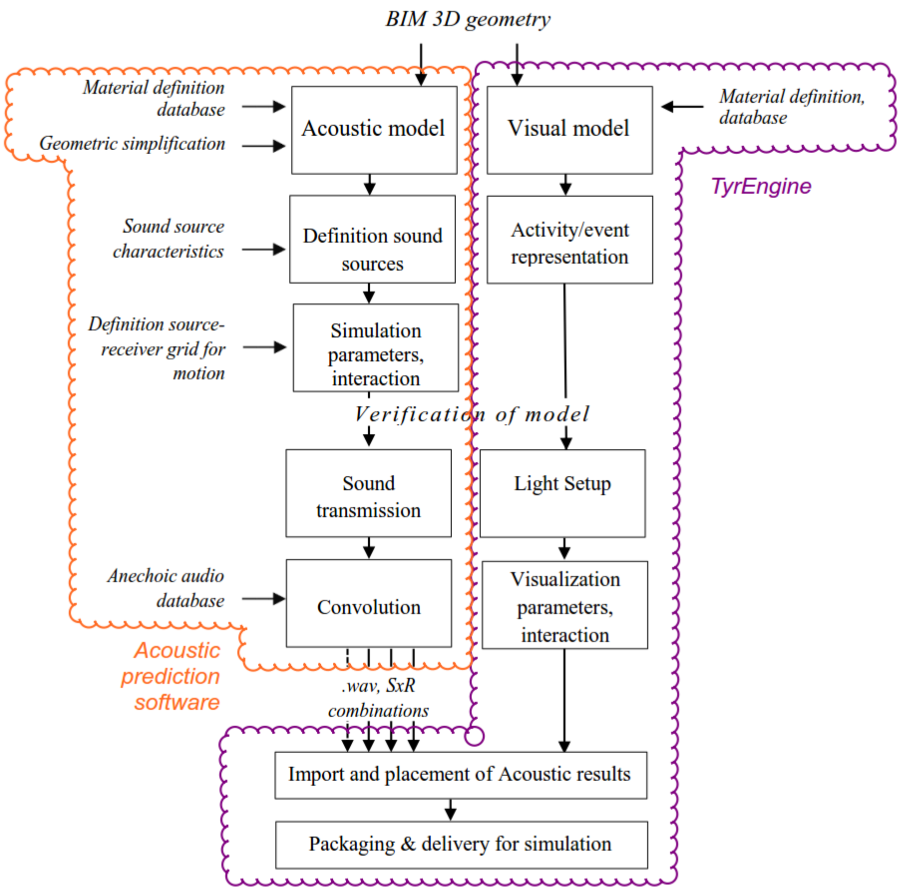

Figure 1. A schematic of the application architecture

4.1 Modelling

4.1.1 The visualization model

The visualization model is initially prepared in the native CAD/BIM application. Material definitions are, in possible extent, made here. The model/models are later imported and verified in TyrEngine. Requirements for data input structures have been met with the use of TyrEngine supporting formats such as .DWG, .DXF, .FBX, .MAX and .OBJ. Manual geometry and material definitions are only necessary if missing in the imported data, making the preparation of the visual model efficient. The geometry is supplemented with visual elements such as human beings, machines, furniture etc., is lacking in the BIM model.

4.1.2 The auralization model

Depending on model complexity, the BIM/CAD model is sometimes necessary to simplify through 3D modelling software. This if necessary to speed up calculations. Material data is assigned manually in acoustic prediction software, dependant on the composites of the spatial boundaries.

4.2 Calculation of light and sound transmission

4.2.1 Light transmission

Real-time graphics are generated through the DirectX 11 Pipeline. Light transmission is calculated using the ray-traced distance field soft shadows function in UE4. The graphics module allows dynamic as well as partially and fully static lighting. Change of light exposure when moving from a dark to lit space is integrated using active eye adaption, emulating the pupil adaption of the human eye. Besides these main functions, more detailed techniques are available and incorporated to maximize the authenticity of the visualization.

4.2.2 Sound propagation

Within acoustic prediction software, sound sources are staged in accordance with the decided scheme of activities and events for simulation. These sound sources correlates to a visual representation of for example people communicating or machines in operation. Room impulse responses, RIRs, are calculated between all source and receivers combinations using geometrical acoustics. Image source modelling for early reflections and ray-tracing adaptations for late energy reflections.

4.3 Motion interaction

Acoustically coupled motion has been added by calculating receiver points in a grid like pattern with fixed distance between points. Distance between receiver points depend on the size and geometry of the simulated environment, striving for a smooth transfer between points. RIRs are convolved with anechoically recorded audio relevant to chosen activities and imported to the TyrEngine as audio. Each calculated source-receiver grid point is active within a geometrical zone spanning 0.5 x distance to adjacent points. Motion occurs through keyboard-controls. Grid point activation connected to current position is enabled through the proximity trigger function of UE4. To handle grid-point crossover, a transition zone is utilized between each position, approximately 10% of the point distance. This transition zone ensures no audible artefacts such as clicks during transition to another grid point as the user moves in the environment. Audio is looped in each position and synced between positions to create a cohesive auditory environment while moving in the space. Receiver point dispersion is depicted in figure 2.

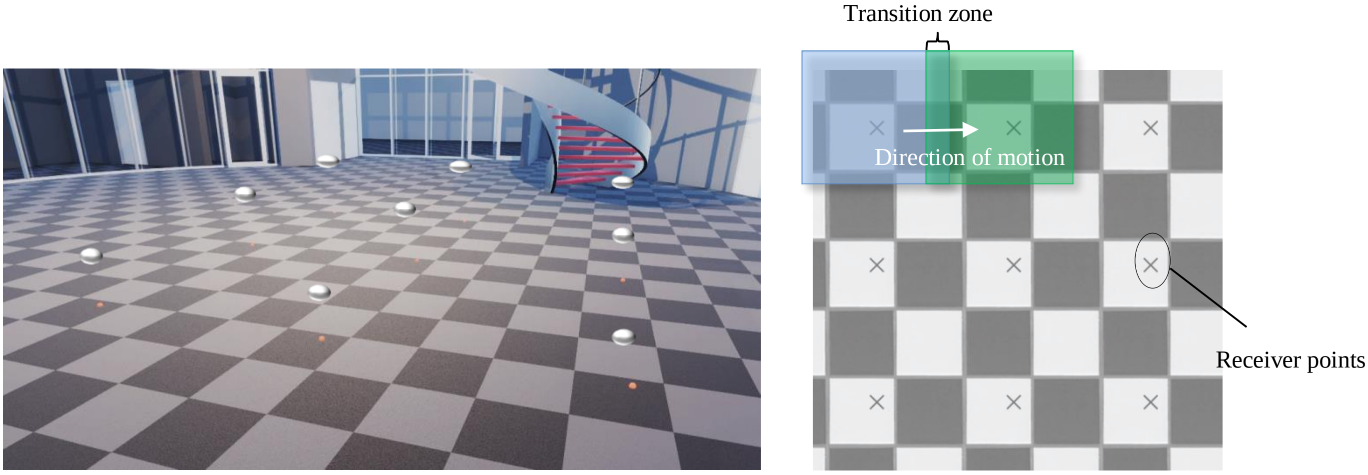

Figure 2. Receiver grid points used for auralization. To the right a schematic of the active zone for each receiver and transition zones for user motion.

4.4 Packaging

The resulting model containing visualization and auralization data are packaged as an installation file for digital redistribution.

4.5 Audiovisual simulation

Binaural, single-screened simulation will first and foremost be utilized for audiovisual reproduction during simulation as it offers mobility and enables discussions based on simulations to occur during project group meetings. For crucial decisions within the planning process, specific sessions will be organized and occur in an acoustically treated studio. Auralization will be performed through an ambisonics decoded sound field. Visuals will be displayed using a projector.

5. Using TyrEngine in the planning process

The updated version of TyrEngine including auralization has recently started to be used in Tyréns currently active projects. Initially for a project that concerns the planning of a new hospital wing. Simulations have been incorporated in order to evaluate background sound levels of ventilation and medical equipment in operating theatres. The simulations include the operation of stationary medical equipment, sound from ventilation and verbal communication between medical staff for reference between wanted and unwanted sound. Ventilation sound levels have been provided by the projects mechanical engineer and recalculated to sound pressure levels by the projects team of acousticians. Sound from medical equipment have been recorded in-situ for practical reasons, accepting near-field recording artefacts. All sound sources are visually represented in the model, most already included in the project BIM model. A still frame from the simulation can be seen in figure 3.

Figure 3. Still frame from test case Operating theatre

6. Summary and future work

This project aims to include possibilities of performing auralization in conjunction with visualization as a part of the application TyrEngine. Necessary preparation of such hybrid simulations need to be efficient, keeping additional costs low. With the introduction of BIM and shared model platforms alongside more efficient execution of visualization and auralization, applications directed towards use in the building planning process can be discussed. TyrEngine with added features is now able to provide acoustically and visually correlated motion. Based on a game engine structure there are possibilities of adding additional features to the application in the future.

Acknowledgements

We would like to thank our colleague Martin Höjer for valuable input regarding the content of this paper and Tyréns AB for supporting the development of this application.

References

[1] Vorländer, M., Schröder, D., Pelzer, S. and Wefers, F., ”Virtual reality for architectural acoustics”, *Journal of Building Performance Simulation,* Vol. 8, No. 1, 15-25, (2015)

[2] Savioja, L., Huopaniemi, J. and Lokki, T., “Creating Interactive Virtual Acoustic Environments” *Journal of the Audio Engineering Society,* Vol. 47, No. 9, (1999)

[3] Lindebrink, J. and Forssén, J., “An interactive auralization method using real-time sound sources”, Proceedings of the 41st International Congress and Exposition on Noise Control Engineering (InterNoise2012), 19-22 August 2012, New York City, USA (2012)

[4] Moloney, J. and Harvey, L. “Visualization and ‘Auralization of Architectural Design in a Game Engine Based Collaborative Virtual Environment”, *Proceedings of the Eight International Conference on Information Visualisation* (IV’04), London United Kingdom, 14-16 July 2004 pp. 827-832

[5] Humbert, P., Chevrier, C. and Bur, D., “Use of a real time 3D engine for the visualization of a town scale model dating from the 19th century”, *Proceedings of the CIPA*, Prague, Czech Republic, 12-

16 September 2011

[6] Indraprastha, A. and Shinozaki, M, “The Investigation on Using Unity3D Game Engine in Urban Design Study”, *Journal of ICT Research and Applications*, **Vol. 3**, **No. 1**, 1-18, (2009)

[7] Ozawa, K., Ohtake, S., Suzuki, Y. and Sone, T., “Effects of visual information on auditory presence”, *Acoustical Science and Technology*, Vol. 24, No. 2, 97-99 (2003)

[8] Larsson, P., Västfjäll, D. and Kleiner, M., ”Auditory-visual interaction in real and virtual rooms” Proceedings of the Forum Acusticum, 3rd EAA European Congress on Acoustics, Sevilla, Spain (2002)