Development of Accurate and Fast Acoustic Calculations using Olive Tree Lab - Acoustics Lib

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ABSTRACT

- OTL-Acoustic Lib is a reusable and extensible code library for the development of accurate acoustics calculations for 3D environments.
- The library allows the development of various software applications for acoustics calculations.
- The Acoustic Library is developed on top of PEMARD Framework
- It is presented a practical applications based on this approach.

INTRODUCTION

Calculations for acoustics simulations have been a complicated subject and various methods have been developed over the past year for the simulation of various acoustical phenomena. A new approach is presented, based on specific PEMARD framework that supports the implementation of fast and accurate acoustics calculations under a unified approach. On the PEMARD framework it has build a code library, named OTL-Acoustics Lib, which implements accurate acoustics calculations for 3D spaces. In this presentation, we present OTL-Acoustics Lib and its implementations while presenting evaluations for the accuracy of the library's calculations.

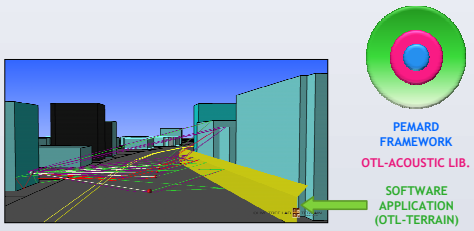
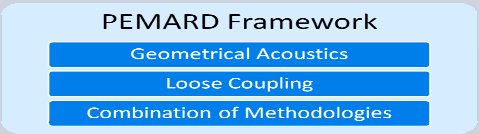


Figure 1. Relationship between PEMARD Framework, OTL- Acoustics Lib and a custom software application.

PEMARD FRAMEWORK

PEMARD framework is a software architectural model which outlines a pattern that can be used in sound propagation calculations and defines a process for the calculation of sound propagation in 3D environments. It sets distinct steps in the process of sound propagation calculations by separating concerns in that process and designates interfaces between these steps. Also, it provides the infrastructure for the communication between these steps. As a result, the framework becomes a collection of several loosely coupled cohesive components which interoperate, based on well-defined interfaces for sound propagation calculations in a 3D environment.

A *loosely coupled model* is one in which each of its components has, or makes use of, little or no knowledge of other separate components. Loose coupling results in the extensibility and modularity of the model and makes it ideal for customization based on needs. At the same time, it provides the interfaces which ensure the interoperability between different components from different research areas.



The framework defines four separate calculation steps:

- **model optimization,**
- **pre-processing,**
- **sound propagation path detection,**
- **sound propagation path calculation.**

These steps are independent and communicate only through clearly defined interfaces. As a result, different implementations of each part can be combined based on the needs of different calculation methodologies.

The framework is based on geometrical acoustics for sound path detection. Geometrical acoustics can be defined as the description of sound propagation in terms of *sound rays or sound paths*. Geometrical acoustics is widely used in current commercial software applications which deal with acoustics calculations [2] [3] [4]. It is also the dominant approach in real time approaches for audio rendering in games [1][5] [6] [7].

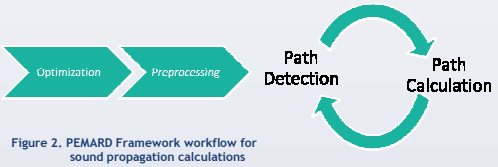


Figure 2. PEMARD Framework workflow for sound propagation calculations

Figure 3. PEMARD Framework serving as the trunk for the development of customized, extensible acoustics calculations.

OTL ACOUSTICS - LIB

OTL-Acoustics Lib is an implementation of acoustics calculations based on the PEMARD Framework.

- It detects *sound paths* using:
  - visibility tracing techniques alongside the image source method for reflections
  - an in-house developed algorithm for diffraction detection, based on the Broyden-Fletcher-Goldfarb-Shanno (BFGS) numerical optimization method.
- It calculates *reflection coefficients* for finite reflectors based on:
  - the spherical wave reflection coefficient
  - a correction for Fresnel zones [8] [9], diffractions based on Salomon's ray model for outdoor sound propagation [10], atmospheric turbulence and atmospheric absorption [11].

EVALUATION OF OTL – ACOUSTICS LIB

Kourion: an ancient Greek theatre in Cyprus

OTL-Acoustics Lib was used to develop the OTL-Terrain Prediction software application, used for the simulation of sound propagation in Kourion [12], an ancient Greek theatre in Cyprus. In Fig 4. we present the comparison of calculated results for excess attenuation together with measured data.

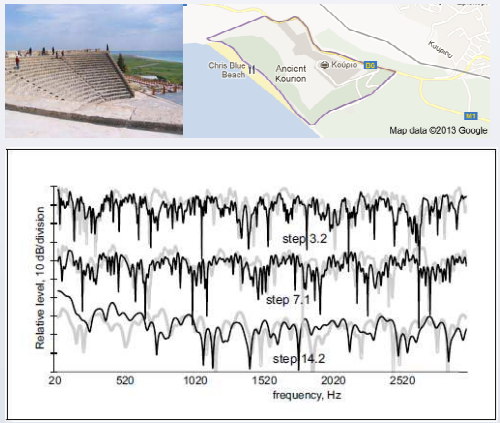


Figure 4. Sound measurements (in grey) and simulation results including second-order diffraction at three Kourion steps, 3rd, 7th, 14th, out of a total of 17 [12].

OTL-Terrain results comparison with ISO 9613-2

By chosing typical scenarios, it has been compared measurement and results of OTL-Terrain, and results from ISO 9613-2 [13] calculations. Fig. 5 shows the respective comparison.

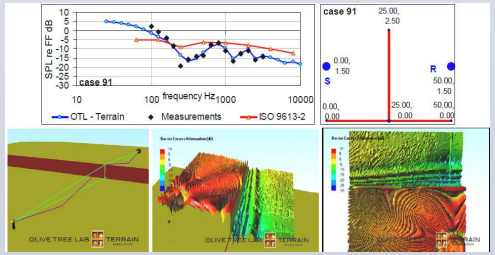


Figure 5. Sample case used for comparison with ISO 9613-2 [13].
Top graph shows the comparison of the results with measurements, From bottom left figures: configuration side view, sound paths and detailed mapping of the area.

By evaluating the results it can be concluded that OTL-Acoustics Lib results have a good matching with measurements in both cases and perform better that other methods, like ISO 9613-2.

OTL-TERRAIN IMPLEMENTATION

To take in account phenomena combining outdoor sound propagation, sound transmission and room acoustics at the same time, and to simulates sound propagation in a three dimensional environment, using the principle of sound rays to detect sound paths.

Thansk to OTL-Acoustic Lib. - The OTL - Terrain applications takes in account: intensity with distance, interaction with the atmosphere, reflections and diffractions, sound transmission and refraction properties.

Implemented methods are:

- Hadden & Pierce Diffraction 3D model implemented with finite impedances faces using Salomons semi-analytical method including ground effects. Multiple barrier diffraction is calculated in a recursive way at any diffraction order.
- In-house sound path detection methods.
- Ground effect using the One Parameter Theory of Chessell based on Delany and Bazley.
- Reflections from finite surfaces based on Clay-Medwin's work to include Fresnel zones contribution at any order level.
- Atmospheric absorption based on ISO 9613 -1.
- Turbulence coherence factor based on HARMONOISE WP3
- Version 1.4 also includes ISO 9613-2 calculation methods.

It is based on high frequency resolution calculations, which can also be seen in 1/3 and 1/1 octave bands after being appropriately averaged.

OTL-ACOUSTICS LIB BENEFITS

OTL-Acoustics Lib has the following benefits for software engineers a) It is build on top of PEMARD framework, thus allowing further customization by the addition or removal of various components of the calculation b) it provides a default calculation behavior for the simulation of sound propagation in 3D spaces c) its default behavior has been used in commercially available software applications, therefore it has been evaluated for its accuracy and speed and it has been shown that it can simulate accurately sound propagation in 3D spaces.

CONCLUSIONS

OTL-Acoustics Lib is a commercially available library that provides accurate and flexible calculations for sound propagation in 3D spaces. We have demonstrated the flexibility of our approach and the possibility of numerous applications of OTL-Acoustics Lib in various acoustics calculations problems

References

[1] P. Charalampous and P. Economou, "A framework for the development of accurate acoustic calculations for games", in AES 49th Conference: Audio for Games, London, (2013.)

[2] "ODEON Room Acoustics Software, ODEON", [Online]. Available: http://www.odeon.dk/acoustics-simulation-software. [Accessed 2012].

[3] "EASE - Enhanced Acoustic Simulator for Engineers", AFMG, [Online]. Available: http://ease.afmg.eu/. [Accessed 2012].

[4] "OTL Terrain," PEMARD, [Online]. Available: http://www.otlterrain.com/. [Accessed 2012].

[5] C. Schissler and D. Manocha, "GSound: Interactive Sound Propagation for Games", in AES 41st Conference: Audio for Games, London, (2011).

[6] T. Funkhouser, N. Tsingos, I. Carlbom, G. Elko, S. Mohan, J. West, G. Pingali, P. Min and A. Ngan, "A beam tracing method for interactive architectural acoustics", J.Acoust. Soc. Am. Vol. 115, no. 2, 739-756, (2004).

[7] N. Tsingos and J. Wenyu, "Using programmable graphics hardware for acoustics and audio rendering", Journal of the Audio Engineering Society, vol. 59, no. 9, 628-646, (2011).

[8] C. S. Clay, D. Chu and S. Li, "Specular reflections on transient pressures from finite width plane facets", J.Acoust. Soc. Am, vol. 94, no. 4, 2279-2286, (1993).

[9] T. Embleton, J. Piercy and G. Daigle, "Effective flow resistivity of ground surfaces determined by acoustical measurements", J.Acoust. Soc. Am, vol. 74, 1239-1244, (1983).

[10] E. Salomons, "Sound Propagation in Complex Outdoor Situations with a Non-Refracting Atmosphere: Model Based on Analytical Solutions for Diffraction and Reflection", Acta Acustica, vol. 83, 436-454, (1997).

[11] R. Nota, R. Barelds and D. Van Maercke, "Harmonoise WP 3 Engineering method for road traffic and railway noise after validation and fine tuning," HARMONOISE, (2005).

[12] P. Economou, P. Charalampous, "The Significance of Sound Diffraction Effects in Simulating Acoustics in Ancient Theatres", Acta Acustica, vol. 99, no. 1, 48-57, (2013).

[13] P. Economou, P. Charalampous, "A comparison of ISO 9613 and advanced calculation methods using Olive Tree Lab-Terrain, an outdoor sound propagation software application: Predictions versus experimental results", Proceedings of the Institute of Acoustics, Vol. 34. Pt.1. (2012).