Real-time simulation of sound propagation effects in complex multi-room environments

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Context

The REVES group at INRIA Sophia Antipolis (http://www-sop.inria.fr/reves) develops graphics and audio rendering algorithms for interactive applications, audio-visual production and post-production and virtual reality.

In this context, we develop solutions to render 3D audio for multiple virtual sound sources in complex environments. A key aspect to realistic 3D audio rendering is modelling of sound scattering effects off the surfaces and objects that are responsible for the reverberation effect. This effect is the primary auditory cue used by listeners to assess the size and characteristics of the environment. However, computing realistic reverberation effects, consistent with a 3D model of the environment is generally time-consuming and difficult to achieve in interactive applications.

Objectives

In this project our goal is to provide interactive audio rendering (auralization) of physically-based sound scattering effects in environments of large complexity (e.g. detailed game levels or models acquired using range-scanning). We propose to explore the combination of a GPU-based solution, improving the work of [2] with a model of higher-order scattering dedicated to reverberation effects, especially in an indoor multi-room context.

The goal of this project is twofold:

1. First, design a new approach for reverberation effects which can be efficiently controlled using a 3D model of the environment. Artificial reverberation filters are traditionally controlled with a few high level parameters directly defined on the filter (reverb time, decay rate for different frequencies linked to the size of the room, etc.) [1]. Each of this parameters influences the shape of the filter which is usually modeled as an exponentially decaying noise.
   Such approaches offer a very efficient processing framework but are hard to link to geometry and have been devoted to the rendering of "single-room effects".

   In this project, we propose to combine a cell + portals spatial subdivision structure with pre-computed filtering effects stored at the interface between cells. Using a cell-adjacency graph, it should be possible to propagate reverberation effects very efficiently in complex multi-room environments without requiring tracing rays or beams at run-time [3]. Pre-computation of the filtering effects for each cell interface can be done off-line through Monte-Carlo path tracing or using simpler statistical approximations for faster, yet realistic effects.

2. Second, combine this late reverberation model with a GPU-based calculation of early scattering effects similar to the Instant Sound Scattering (ISS) of [2], that can handle scenes with high-local complexity.
   ISS is a GPU accelerated approach aimed at computing first order sound diffraction/reflection off complex surfaces. Following the Kirchhoff approximation, it evaluates an integral on all surfaces visible from the sound source for a set of frequencies. The GPU is used for 1) sampling the visible surfaces, 2) evaluating the integrand on each pixel and 3) performing hierarchical integration using mip-mapping. The resulting complex value obtained for each considered frequency can be used to reconstruct a filter to render the corresponding effects.
   In the context of this project ISS would have to be improved in order to properly account for propagation delays and efficiently handle multiple sources.

References

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