A General Model for the Simulation of Room Acoustics Based On Hierarchical Radiosity

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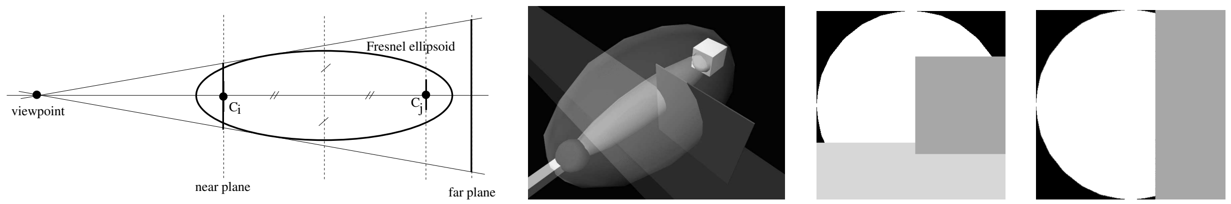
We present a new method to compute the impulse response (IR) of a given virtual room based on hierarchical radiosity. Unlike previous work, our approach can treat complex geometries and is listening-position-independent. Moreover, complex phenomena such as sound diffraction are also taken into account.

The acoustical quality of a room may be evaluated from two points of view: objective criteria which can be measured and subjective appreciation by listening. These two ways however, usually require the knowledge of the room *impulse response* at the listening position. The impulse response of a room may be seen as the pressure response of the room when the source emits an instantaneous impulse (Dirac signal). It is a digital filter that encodes all sound reflections through time from the source position to the listening position. By convolving this filter with a rough sound signal, the virtual sound field is made audible. This process is referred to as *auralisation* [1, 2]. Two standard methods for IR computation are ray/cone-tracing and image sources methods [1, 2]. However, they quickly become impractical for complex geometries or high orders of reflection. They do not take into account complex phenomena such as diffraction by partial occluders. Moreover, they are listening-position dependent, therefore the complete solution must be recomputed if the listener is moving which can be limiting for virtual acoustics applications [1, 2].

We present a new approach to compute the IR of a virtual room based on a hierarchical- radiosity-like solution with general reflectance distributions [3]. We propagate energy from patch to patch as in the classic hierarchical radiosity method. Since sound propagation time cannot be neglected, we store an energy repartition through time for each surface corresponding to the list of echoes that reach the surface. This energy repartition through time - or *echogram* - is computed for various frequencies (generally octave bands) since reflection functions, source and microphone directivities as well as propagation medium scattering are frequency dependent. We approximate the attenuation factor due to diffraction by partial occluders by evaluating a frequential extended sound visibility term. This term is computed by counting the proportion of the first Fresnel ellipsoid - where most of the energy propagates - blocked by occluders. The first Fresnel ellipsoid is defined by $\{M \in I\!R^3 / C_iM + MC_j = C_iC_j + \frac{\lambda}{2}\}$ where C_i is the center of a patch P_i, C_j is the center of a linked patch P_j and λ the wavelength of the sound wave. We use graphics hardware for fast calculations by evaluating occlusions using the Z-buffer (Figure 1).

Phase information is also essential in order to reconstruct the IR. Thus, we represent echoes as complex numbers corresponding to modulus and phase. Once the sound radiosity solution is computed, the IR can be evaluated by re-projecting each echo stored on each surface onto the listening point. A short sampled impulse response of a basic bandpass filter is associated with each complex echo. These short IRs are then delayed and summed to obtain the final IR.

Our new method allows for using the appropriate number of patches for each frequency band, thus leading to an "optimal" usage of the computing ressources. Complex propagation phenomena are taken into account and final rendering times of less than a second make our approach promising for virtual acoustics applications. Validation of our algorithm with measured IRs of existing concert halls and rooms is currently in progress.



(a) (b) (c) (d)

Figure 1: Using graphics hardware for sound visibility calculations. (a) Viewing frustum (b) 3D view of microphone, source, occluders and Fresnel ellipsoids for 400 and 4000 Hz. (c) Visibility from microphone at 400Hz. (d) Visibility from microphone at 4000Hz. Visibility term is the percentage of white pixels in the view.

References

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