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Using Raytracing for Accurate Sound Simulation in Gaming and Virtual Environments

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Introduction

Raytracing refers to the process of determining the light transport between various scene elements – a ray is cast from a view camera through a 2D viewing plane, out onto a 3D scene, and on contact with an object, the ray is "traced" back to the light source [1]. This project takes this rendering concept, and applies the methods to a similar physical phenomenon – sound. By exploring raytraced audio, this project aims to develop an accurate algorithm for modelling sound propagation and rendering.

This project seeks to apply raytracing methods and methodologies as proof-of-concept towards the simulation of acoustic phenomena in virtual environments, implemented as a visualisation-based solution.

Research and Key Points

- Most use wave-based methods for accuracy (Such as FEM, BEM, FEM-BEM, FDTD, or other hybrid methods)
- Similar techniques already exist vis-à-vis geometrical acoustics
- Wave-based methods, while accurate, can be heavily resource intensive
- Geometric acoustics trade accuracy for speed – there is a trade-off between perceptual authenticity and model complexity [2]
- Geometric acoustics are good at high frequencies, can handle large environments, and both dynamic sources and listeners, while wave-based methods allow for modelling wave effects like diffraction and interference at all frequencies with arguably higher accuracies, albeit at a higher computational cost [3].

Implementation

The goals behind this project were to implement and integrate a raytraced audio algorithm into a 3D virtual environment, rendering sound as abstracted "rays," using a graphics API such as OpenGL or Vulkan, optimised to run seamlessly at a stable 60 frames per second. The implementation would be relatively simple, including at minimum a player, an object, and a non-symmetrical room. Once modelling of ray reflection and decay/absorption was implemented, this would expand to include occlusion and reverberation as factors influencing ray propagation and decay.

Results, Discussion, Future Work

Due to time constraints and a number of personal events, this project was never fully completed. Thus, any future work should first cover a basic OpenGL implementation. This prototype should be compared to other geometric acoustics solutions, and then expanded to include more physical phenomena (e.g., diffraction, distortion, etc.). Finally, deeper exploration into alternative graphics APIs should be considered, both for algorithmic efficiency, and for more potential accuracy towards modelling real-world acoustics.

References

[1] T. Akenine-Moller et al., Real-Time Rendering, 4th ed., Boca Raton: CRC Press, 2018.
[2] V. Martin, I. Engel and L. Picinali, "Effects of Geometrical Acoustics Model Simplification on Binaural Reverberation," *IEEE Transactions on Audio, Speech and Language Processing,* vol. 33, pp. 3480-3493, 2025.
[3] E. Deines, M. Bertram, J. Mohring, J. Jegorovs, F. Michel, H. Hagen and G. M. Nielson, "Comparitive Visualization for Wave-based and Geometric Acoustics," *IEEE Transactions on Visualization and Computer Graphics,* vol. 12, no. 5, pp. 1173-1180, 2006.