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Virtual Lab for Room acoustics and Reverberation time simulator

Project Report Submitted to:

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Room Acoustics and Reverberation Simulator

Physics Project Report

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1. Objective

The primary objective of this project is to develop an interactive **Room Acoustics and Reverberation Simulator** that dynamically visualizes and calculates how reverberation time (RT60) is affected by room dimensions, surface materials, and sound frequencies. The simulator aims to enhance understanding of room acoustics by providing a hands-on tool for analyzing the impact of material choices and space design on sound clarity and quality.

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2. Methodology

The project uses **Three.js**, a 3D rendering library, Javascript, HTML, CSS to create an immersive visualization of a room with customizable dimensions and materials. The methodology involves:

1. **Setting up the 3D Scene**: The room and sound source are modeled in a 3D space with adjustable dimensions for length, width, and height.
2. **Material Modeling**: Each wall material is assigned specific sound absorption coefficients for various frequencies (125 Hz to 4000 Hz).

3. **Reverberation Time Calculation**:

The first step to calculate the reverberation time is to calculate the Sabins with the below equation.

Formula for Sabins:

$$a = \Sigma S \alpha$$

Where:

Σ = sabins (total room absorption at given frequency)

S = surface area of material (feet squared)

α = sound absorption coefficient at given frequency or the NRC

After we calculate a, we can then use the Sabine Formula to calculate the reverberation time.

Sabine Formula:

$$RT60 = 0.049\ V/a$$

Where:

RT60 = Reverberation Time

V = volume of the space (feet cubed)

a = sabins (total room absorption at given frequency)

4. **User Interaction**: Inputs for room dimensions, material type, and frequency are taken via sliders and dropdown menus, and the results are updated in real-time.
5. **Animation**: A dynamic wave visualization demonstrates how sound propagates within the room.

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3. Novelty

The Codes and programs behind this project can be accessed here:
Link:
https://1drv.ms/t/c/aa2ee3b2c07258b1/EaIfMGbhPC9AmrylopEcqm0BkvhyjsWrriUGFUPfG0HPyw?e=xrTva3

https://1drv.ms/u/c/aa2ee3b2c07258b1/EYKKEcXFgrVEkgsXnUzwi6UBLVS3BvW_eGD1kl8hcKluDg?e=YhGWyT

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4. Future Works

To enhance the simulator further, the following features could be incorporated:

1. **Enhanced Material Database**: Include a broader range of materials with detailed absorption coefficients, such as glass, metal, and fabric.
2. **Directional Sound Source**: Allow users to place the sound source at different locations and visualize sound propagation patterns.
3. **3D Sound Experience**: Integrate spatial audio to simulate how the room would sound to a listener at various positions.
4. **Multiple Sound Sources**: Add the capability to simulate the impact of multiple sound sources, like a stereo system.
5. **Export Feature**: Allow users to download a detailed report of their simulation for academic or professional use.
6. Advanced graphical representation along with sound ray tracing.

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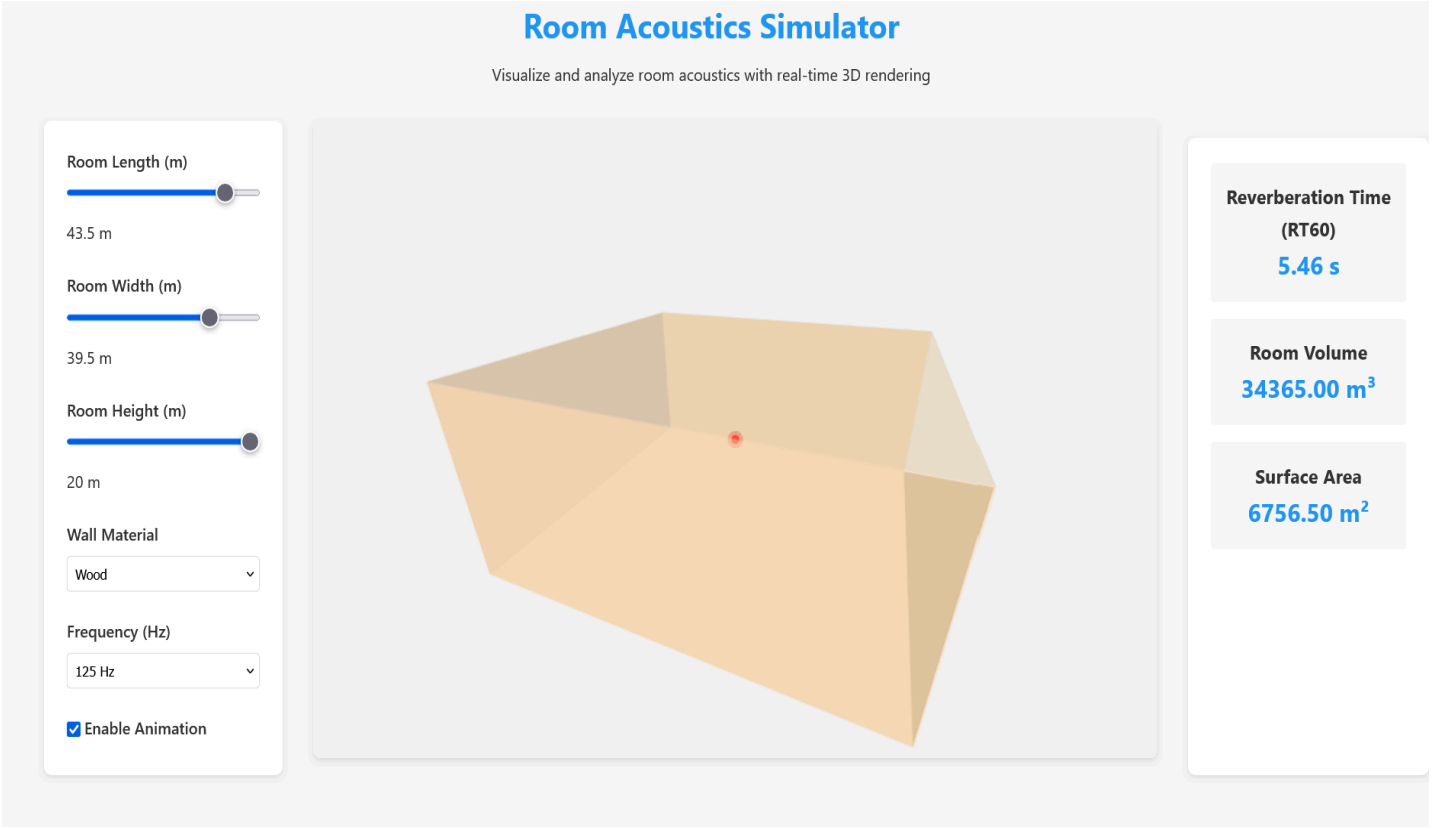
5. Design

The simulator is designed with a user-friendly interface and technical precision:

1. **User Interface**:
    - Sliders for room dimensions (length, width, height).
    - Dropdown menus for selecting wall materials and sound frequency.
    - Real-time display of calculated values for **RT60**, **volume**, and **surface area**.
2. **3D Visualization**:
    - A scaled 3D model of the room is rendered with **transparent walls** to allow internal visibility.
    - Dynamic sound wave animations provide a visual representation of reverberation.
3. **Interactive Feedback**: All inputs dynamically update both the visualization and the calculations, making the system highly responsive.



6. Conclusion

The **Room Acoustics and Reverberation Simulator** successfully demonstrates the interplay between room dimensions, surface materials, and sound frequencies. By integrating scientific calculations with interactive visualizations, the simulator provides a powerful tool for understanding and optimizing room acoustics. This project showcases the potential for blending physics with modern technology to create impactful educational tools and practical design aids.

The simulator has room for further development, but it already serves as a valuable resource for exploring acoustics principles in an intuitive and engaging way.
