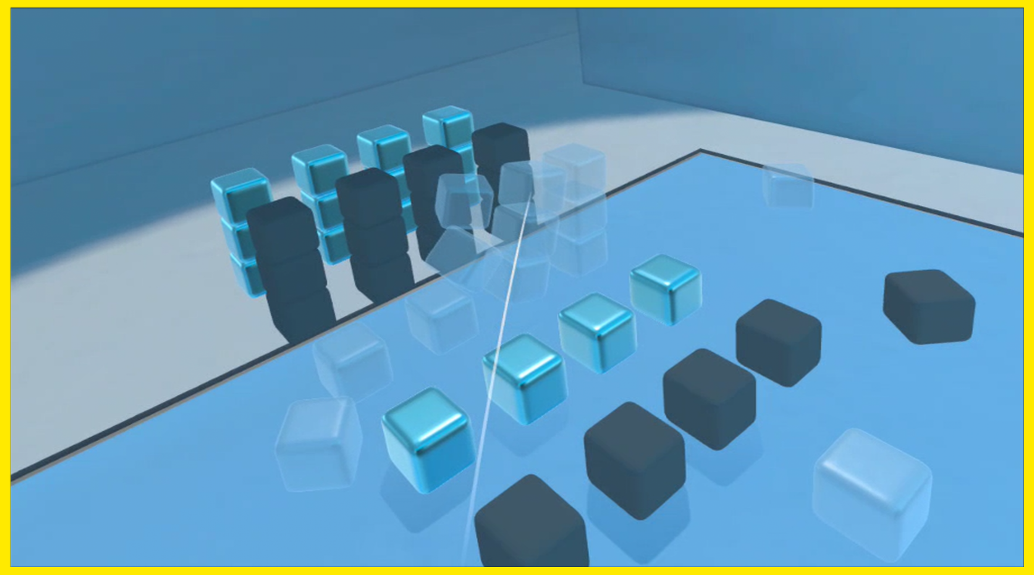
CSE 493V
VR SYSTEMS

Physics Based Sound Simulation

Jiexiao Xu, Nicholas Batchelder
University of Washington

PROBLEM

Precomputed audio is commonly used in interactive applications to provide sound effects. We propose an implementation of physically-based sound simulation, creating a realistic acoustic simulation within Virtual Reality.



RELATED WORK / MOTIVATION

Prior work [Doug L. James and Pai 2006] proposes a real-time sound simulation paradigm. It suggests a pre-computation scheme that pre-processes the global sound radiation effect before runtime. At runtime,it onlycomputes the weighted contribution from sound sources at the listener's location, hiding the cost before interaction.

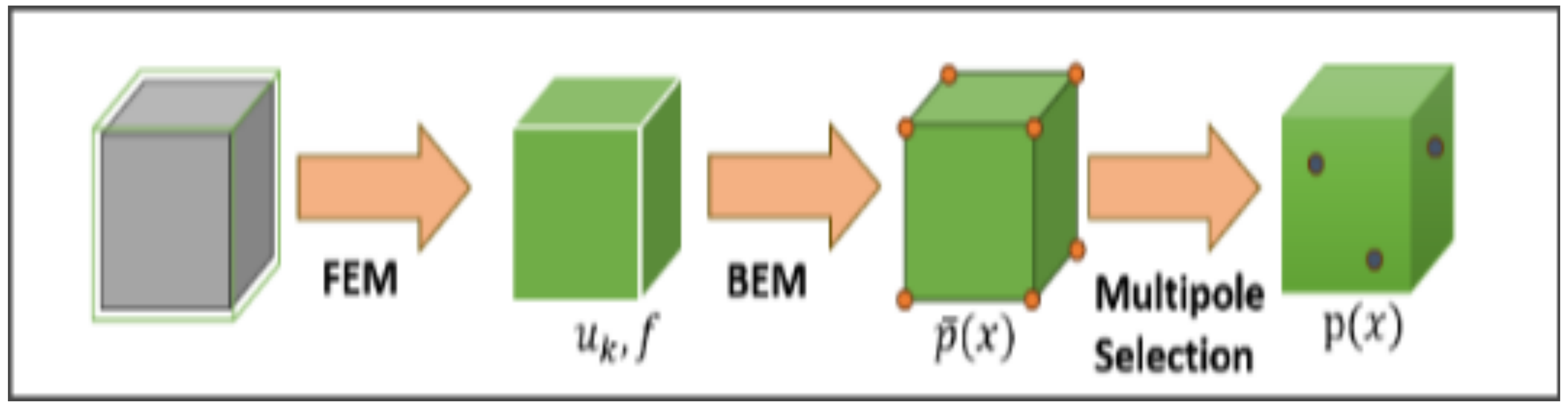
[Wang et al. 2018] suggest a time-domain wave-solver that presents the better-simulated results. However, this method is not feasible on the fly, and uses extensive cloud computation resources.

YOUR APPROACH / SOLUTION

Using an algorithm resolving the sound radiation, we used the pre-recorded data to simulate the sound of an interaction between two objects. Our implementation is able to produce physically accurate sounds with regard to object material and listener position — in real-time.

METHOD / PIPELINE / ALGORITHM/ PROCESS

We simulate sound by using modal analysis to decompose object vibrations into sinusoidal wave components, differentiating materials by their oscillation modes. The wave equation models sound propagation, simplified with a damping factor and solved using the Helmholtz equation in the frequency domain. To enable real-time performance, we approximate acoustic transfer by selecting representative sound sources rather than evaluating all surface vertices. A pre-computation pipeline applies Boundary Element Method (BEM) for sound pressure evaluation and spherical multipole expansion for efficient radiation modeling. An offset surface prevents computational singularities, while weighted least squares optimization determines sound coefficients. A greedy multipole placement algorithm selects optimal sources, reducing computational overhead. In real-time execution, precomputed data is used to generate sound efficiently with frequency-dependent damping.



RESULTS

Our project successfully achieves real-time sound simulation, producing realistic and distinguishable audio for different materials such as bronze, glass, and plastic. While computation times vary due to solver setup overheads, latency is imperceptible to the human ear, ensuring a seamless experience. Although we aimed to quantify error and latency, time constraints limited us to qualitative evaluation. The simulation results for bronze and glass were realistic, but plastic did not fully meet expectations, likely due to unfamiliarity with FEM and BEM tools affecting solver accuracy.

For the demo, we will showcase the real-time aspect by allowing users to interact with virtual objects of different materials in a VR environment. As objects collide, users will hear dynamically generated sounds that reflect material properties, demonstrating the accuracy and responsiveness of our simulation.

Table 1. Computing Time for Different Materials

Material	time
Bronze	33.6235
Glass	10.9968
Plastic	11.3111

Table 2. FEM result for Bronze, Glass, and Plastic

Material	Mode	Frequency (Hz)	X Participation	Y Participation	Z Participation
Bronze	1	101.171	61.245	0.000	0.000
	2	156.719	0.000	63.098	0.000
	3	431.000	22.349	0.000	0.0001
	4	450.849	0.000	0.000	78.859
	5	495.658	0.000	22.491	0.000
Glass	1	165.229	61.181	0.000	0.000
	2	259.775	0.000	62.378	0.000
	3	721.696	22.132	0.000	0.0001
	4	737.924	0.000	0.000	80.261
	5	837.943	0.000	22.922	0.000
Plastic	1	43.949	61.180	0.000	0.000
	2	67.372	0.000	63.468	0.000
	3	183.914	22.520	0.000	0.0002
	4	195.117	0.000	0.000	77.584
	5	210.158	0.000	22.242	0.000

REFERENCES

Jernej Barbič Doug L. James and Dinesh K. Pai. 2006. Precomputed Acoustic Transfer: Output-sensitive, accurate sound generation for geometrically complex vibration sources. ACM Trans. Graph. (2006).

Jui-Hsien Wang, Ante Qu, Timothy R. Langlois, and Doug L. James. 2018. Toward Wave-based Sound Synthesis for Computer Animation. ACM Trans. Graph. 37, 4, Article 109 (July 2018), 16 pages. https://doi.org/10.1145/3197517.3201318