Determining the Speed of Sound in Granular Materials

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Introduction

I started working on this research project in May of 2019 with Professor Derek Richardson and graduate student Joe DeMartini. Our simulations aim to analyze the speed of sound as it propagates through granular, or sand-like materials. We are modeling our simulations after Professor Gonzalo Tancredi's experiments in which they shot a high-speed projectile at a box of compressed sand-like particles. Between different runs we will be changing the confining pressure of the box and quantifying how the speed of the pressure wave changes with different pressures. This project will have implications into the physics of asteroids and asteroid collisions, as asteroids tend to behave like a loose collection of small particles rather than one homogenous material.

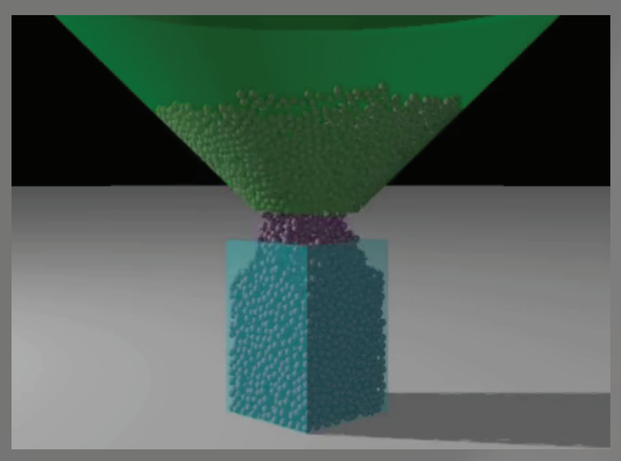

Figure 1: The first stage of the simulation, the filling stage. We fill the box with particles using a funnel.

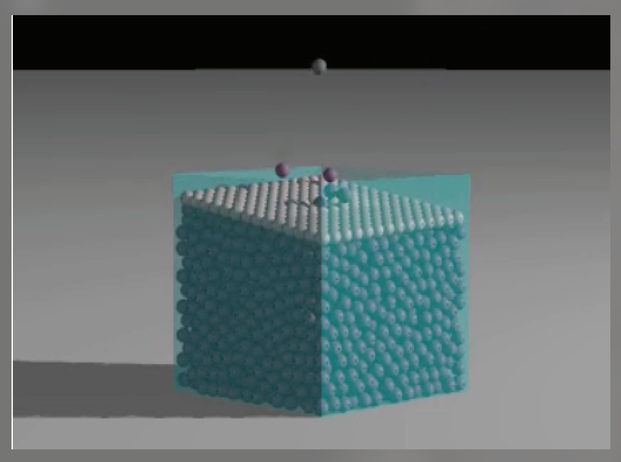

Figure 3: One of the first issues we encountered with the compressing stage. The wall bounces unevely.

Methods

I conducted computational simulations using the N-body PKDGRAV code supplied by Professor Derek Richardson. The various stages of the simulations involve filling a box with particles, compressing the box of particles, and shooting a high-speed projectile at the particles. For each simulation, I was responsible for setting up the simulation, calculating the correct simulation parameters, monitoring the simulation progress, and progressing the simulation to the next stage. I also wrote different python scripts to make the simulation progress more efficiently from one stage to the next and to analyze the physics of the experiment At this point in the research project, we are using the following stages in the simulation: filling up the box of particles with a funnel as shown in Figure 1, compressing these particles with a massive wall with a hole in the middle as shown in Figure 2, then decompressing the particles to a desired pressure, and shooting a projectile at the particles. Once the final stage of the simulation is complete, we will analyze the vertical positions of the particles to identify the speed of the pressure wave.

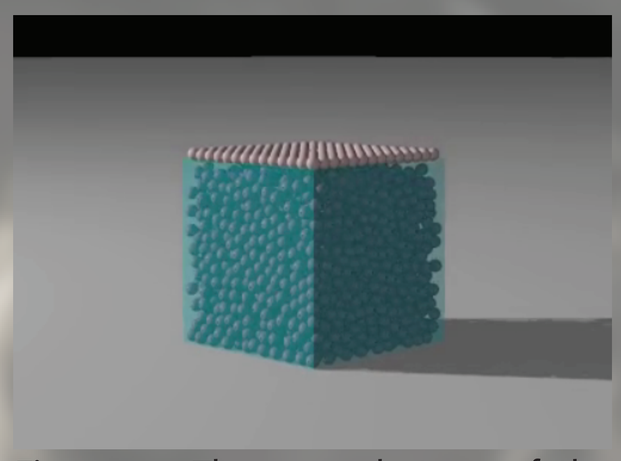

Figure 2: The second stage of the simulation. We compress the particles using an aggregate of particles.

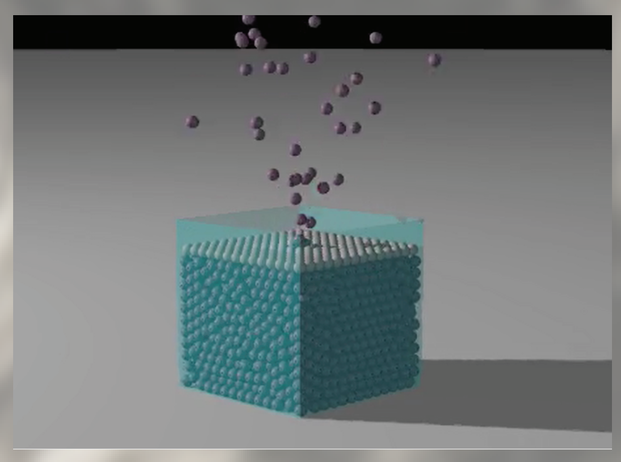

Figure 4: The next issue we encountered with the compressing stage. The particles flow from the hole.

Progress

Throughout this project, we have encountered many different issues that delay the project progress such as technical issues, odd functions of the code, and the simulation not behaving as we expected. We specifically encountered unexpected behavior when we started compressing the box of particles. The first issue we encountered is shown in Figure 3. We placed a massive wall on top of the box and it unevenly bounced on top of the particles. To correct this, we adjusted the parameters of the filling stage to get a more even packing of the particles. After we did this, the wall did not bounce on the particles but instead the particles fountained through the hole. This is shown in Figure 4. We did not expect this behavior, and we are currently trying to understand and diagnose this effect.

Conclusions

In conducting this research project, I learned many valuable skills. Along with becoming more familiar with the physics of small particles and developing advanced computational skills, I gained experience conducting research and collaborating with professors and graduate students. Throughout this project, we had to diagnose multiple conceptual and coding challenges, which involved finding the most accurate yet efficient way to conduct the simulations. I will be continuing with this project throughout the summer and next year. We are beginning to finalize the stages of the simulations and I am excited to start analyzing the simulations once they are finished.

Special thanks to Professor Derek Richardson and Joe DeMartini in the Astronomy Department, Dr. Alan Peel, Mrs. Erin Thomson, and the SDU program as a whole for making this project possible.