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Project: Granular flow dynamics in a rotating drum

The project was to test a theoretical model for the dynamics of granular materials. We chose the specific setup of a rotating drum because we have a nice theoretical prediction for this geometry and it is conducive to prolonged experiments. The equations of motion were derived by considering the material (in our case 1mm diamter glass beads) as a continuum and using continuum mechanics, along with certain assumptions about dominant forces, to formulate equations of motion. For continuum mechanics we need a constitutive relation along with equations of motion to understand how the body deforms given certain stresses.

The first part of the experiment was to determine empirical values for constants in the constitutive law which depend on the material used. To this end we constructed a long inclined plane of adjustable inclination covered with glass beads glued to the board. By releasing a large amount of beads down the plane we could measure the flowing layer depth, the height of the final layer, and the mass flux exiting the bottom of the plane. In this way we could fit many data runs at different inclinations to the constituive relation to determine the constants for our beads.

Once we had an accurate constitutive relation for our material, we were able to test the theoretical model. For this purpose we constructed a transparent drum which could be rotated at various speeds. We used a camera to take images of the beads as they rotated in the drum and used particle tracking software to calculate the velocity field. The particles at the bottom of the drum acted as a rigidly rotating body because the stresses on them were very low. But as they were rotated upwards, they cascaded down to the bottom in a flowing layer. The model predicts a certain shape for the flowing layer, as well at the actual velocity field. The image below shows a slice of the flowing layer near where the particles stop behaving rigidly and start avalanching.

Because the particles in the flowing layer are moving very rapidly, one needs to have a camera with a very high frame rate. The camera we had was able to sustain a frame rate that was only sufficient for low rotation speeds, but a much faster camera is on order and should allow us to make better measurements. Although, we had by no means finished the experiment by the end of the summer, preliminary results indicate that there is significant divergence between the model and the data. This could be due to incorrect assumptions about various terms in the differential equation used to create the theory, or in the constitutive law itself.