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Discrete element modelling of subglacial sediment deformation

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Soft, deformable sediments are often present under glaciers. Subglacial sediments deform under the differential load of the ice, and this causes the overlying glacier to accelerate its motion. Understanding the rheology of subglacial sediment is therefore important for models of glacial dynamics. Previous studies of the mechanical behaviour of subglacial sediments have primarily relied on analytical considerations and laboratory shearing experiments. As a novel approach, the Discrete Element Method (DEM) is used to explore the highly nonlinear dynamics of a granular bed that is exposed to stress conditions comparable to subglacial environments. The numerical approach allows close monitoring of the mechanical and rheological behaviour under a range of conditions. Of special interest is bed shear strength, strain distribution and -localization, mode of deformation, and role of effective normal pressure during shearing.

As a calibration benchmark, results from laboratory ring-shear experiments on granular material are compared to similar numerical experiments. The continuously recorded stress dynamics in the laboratory shear experiments are compared to DEM experiments, and the micro-mechanical parameters in the contact model of the DEM code are calibrated to match the macroscopic Mohr-Coulomb failure criteria parameters, constrained from successive laboratory shear tests under a range of normal pressures.

The data-parallel nature of the basic DEM formulation makes the problem ideal for utilizing the high arithmetic potential of modern general-purpose GPUs. Using the Nvidia Cuda C toolkit, the algorithm is formulated for spherical particles in three dimensions with a soft-body contact model. Scene rendering is performed using a custom Cuda ray-tracing algorithm. Efforts on optimization of the particle algorithm are discussed, and future plans of expansion are presented.