Adaptive particle refinement in terramechanical DEM simulation

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ABSTRACT

DEM is computationally intensive for granular dynamics simulation, leading to a need for efficient strategies. This study explores using local particle refinement, scaling particle size based on expected spatial resolution needs, inspired by adaptive mesh refinement in FEM. Finer particles are used where intense interaction occurs, and coarser particles further away.

We hypothesize this method can maintain good accuracy while reducing particle count and computational effort. Fine particles are used on the soil bed's top, with coarser particles at greater depth, creating a particle size gradient. By adjusting the gradient we introduce a "scaling aggressiveness", allowing control over the trade-off between efficiency and accuracy.

We use triaxial tests to verify that the method is scale invariant. Pressure-sinkage and shear-displacement tests are then used to evaluate the method's effectiveness and accuracy in terramechanics applications. All beds were compared to a reference bed with homogenous particle size, where the mean static sinkage was 1.25 mm for a 50 kPa load. The dynamic sinkage was 73 mm for the full simulation time. For quasi-2D simulations, mild scaling aggressiveness reduced the particle count by 2-4 times with relative error up to 4% for dynamic sinkage (11% for static sinkage). For medium aggressiveness, 4-6 times reduction with relative error of 4% (19% static). For highest aggressiveness, 6-8 times reduction with relative error of 7% (29% static). The internal friction proved to be very resistant to gradient changes, with errors within 1%. When extending the model to full 3D, we estimate up to a reduction in particle count of up to a factor 25.