Level set avatar method for discrete computational analysis of granular systems

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ABSTRACT

The complex, inelastic behavior of granular systems makes them a challenging field of study in formulating continuum plasticity models that describe them. While these models are able to faithfully replicate behavior of granular systems, they are reliant on parameters that must be inferred empirically, such as dilatancy and friction, which are contingent on underlying grain-scale morphology and in-situ conditions. We present a level set-based avatar method for the characterization and simulation of granular materials that directly accounts for grain morphology and in-situ conditions. This allows us to capture the macroscopic plastic behavior of granular systems straight from the microscale.

The level set avatar method is comprised of two processes, characterization and simulation. In the characterization process, an X-ray computed tomographic (XRCT) image of a granular system is converted into digitized level set avatars, where each avatar represents a grain [1]. The avatars capture the size, shape, and positions of all of the grains, thus being able to fully account for grain morphology and in-situ conditions of the experiment.

The simulation process is based on the classical discrete element method [2], but in three dimensions and with the ability to capture shape. The level set representation of grain avatars provide advantages over existing shape representations such as sphere clumping and polyhedral in both faithfulness of shape and computational efficiency.

Our avatar experiment-to-simulation paradigm is carried out through a test case of a tri-axial experimental specimen consisting of approximately 2800 grains. From an XRCT image taken of the specimen, avatars are generated for each of the 2800 grains, and the avatar assembly is compressed tri-axially (Figure 1). The curves obtained show that the level set avatar method is able to capture the stress-strain behavior of the experiment. The difference in the volume-strain behavior may be attributed to the uniform boundary conditions of the numerical simulation, which is an issue that is being addressed.

Overall, the level set avatar method shows promise in being able to directly simulate plastic effects (i.e., grain reorganization) at the grain scale to obtain macroscopic stress-strain quantities.

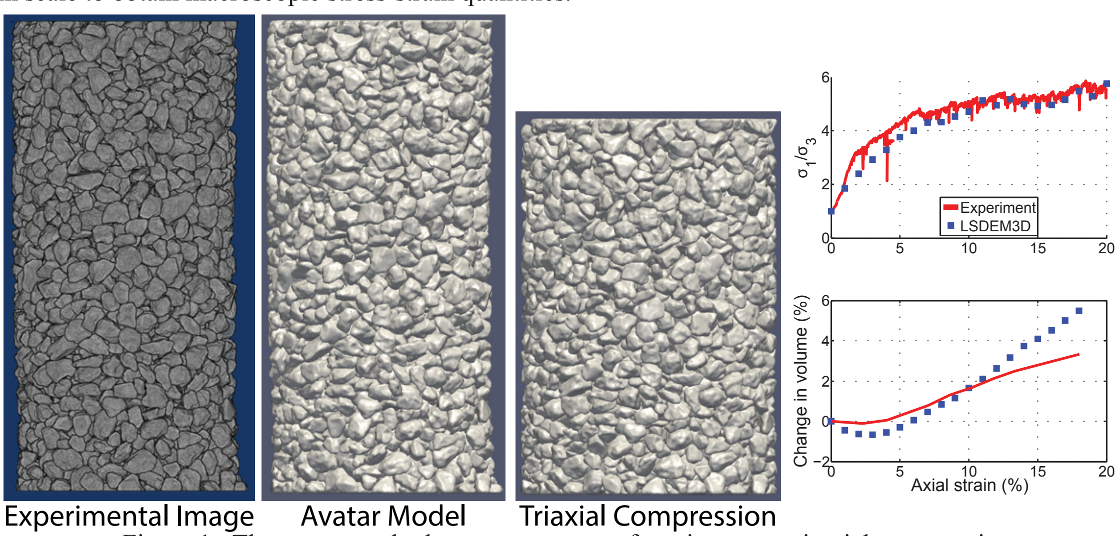

Figure 1. The avatar method test case process, from image to tri-axial compression.

REFERENCES

[1] I. Vlahinic, E. Ando, G. Viggiani, and J. E. Andrade. Towards a more accurate characterization of granular media: extracting quantitative descriptors from tomographic images. Granular Matter, pages 1-13, 2013. doi:10.1007/s10035-013-0460-6.

[2] P. A. Cundall and O. D. L. Strack. A discrete numerical model for granular assemblies. Geotechnique, 29:47-65, 1979.