3rd International Conference on Tomography of Materials and Structures
Lund, Sweden, 26-30 June 2017, ICTMS2017-48-1

Identification and tracking of particles undergoing progressive breakage under stress with 3D+t image analysis

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Keywords: grain breakage, granular mechanics, x-ray tomography, digital volume correlation

Summary: Grain breakage is an interesting phenomena in Geomechanics and Civil Engineering. Grains, when subject to high stresses, break. We are developing techniques that aid in the understanding and characterization of this phenomenon

1. Introduction

Grain breakage is a phenomenon of great importance in a large number of industrial problems. Industrial processes for which grain breakage is important include granular materials being subjected to high stresses (installation of supporting piles into a soil for civil engineering, for petroleum extraction and for wind-turbines as well as for the change in permeability for oil/gas extraction), and when grain breakage is the final objective of a process (crushing of extracted ores from mining, or particles from pharmaceuticals where breakage energy is a significant cost). Multi-scale models for granular media require quantitative measurements coming from experiments. For a complex phenomenon such as grain breakage, a series of high-resolution tomography images are essential, and quantification of key variables related to grain breakage (particle size and shape evolution for example) is required for allowing modelling efforts to progress.

2. Image analysis

The quantification of breakage involves two steps, typically performed separately: grain labelling and grain tracking. Grain labelling provides the ability to interrogate individual grains within a single 3D image of a granular assembly. For this sort of image, this is typically done with a morphological watershed.

Tracking allows particles to be followed through the different time steps while the granular system evolves under mechanical load. This is necessarily done by recognising particles – either based on their characteristics [1] or based on their image [2] with Discrete-Digital Volume Correlation.

Grain labelling and grain tracking have until now been applied sequentially and independently, thus accumulating error. We are developing a framework in which synergy between these processing steps can be improved in order to reduce overall error of labelling and tracking – in short the development of a full 4D (3D+t) analysis of these data sets.

This will involve the creation of novel techniques that at the first level improve the quality of grain labelling by taking into account the physical properties of granular materials (for example initial grain sizes and shapes, as well as steric exclusions, and the conservation of mass) in the formulation of the labelling problem. We have studied the effect of parameters such as the watershed level, in both the widely used morphological variant and the newly introduced graph based Hierarchical variant, on the quality of segmentation obtained. The effect of noise has also been studied widely in a bid to understand its effect on segmentation quality and also to define an implicit or explicit metric for the evaluation of segmentation quality, with the use of both controlled synthetic images[3] as well as real tomography data.

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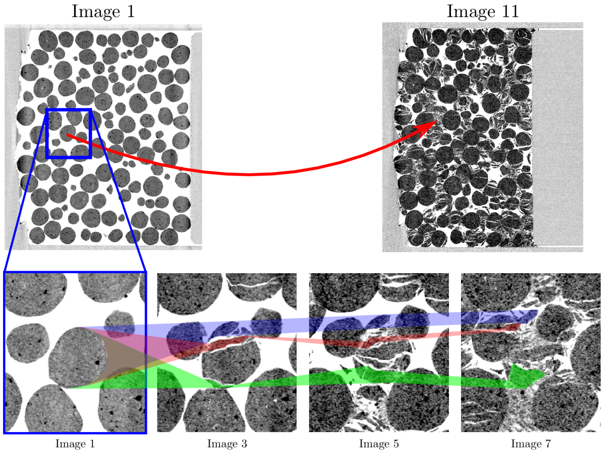

Figure 1: Breaking across Multiple Time Steps

Starting from an acceptable initial labelling, the framework we propose to develop will track and label subsequent steps iteratively allowing the labelling of each identified particle to be refined. Grains avoiding capture with such a procedure will be considered as broken and consequently recaptured, as illustrated in Figure 1.

The proposed algorithm involves the labelling of grains in the initial image. Consequently, grains obtained are tracked through a series of timesteps. During tracking through a particular timestep, for each grain, a match quality is obtained. If the match quality is less than some threshold quality, the current timestep is relabelled and broken grains are sought after. Broken grains are obtained in a hierarchical manner, such that semantic details is distilled from the parent (grain) to the child (fragment).

3. Conclusions

The proposed algorithm will allow significant improvement of the labelling and tracking of images where particles do not break, and will allow handling of the difficult case where particles break, allowing an unprecedented generation of micro structural measurements to be made.

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