Surface size-frequency distribution of accumulating boulders using discrete element simulations of spherical particles in 3D

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Several spacecraft have revealed new detail about small bodies such as asteroids, comets, and small satellites. Images from Hayabusa, Hayabusa2, and OSIRIS-REx showed more boulders on the surfaces than originally expected. Owing to the high resolution at which images were taken, a number of boulders could often be observed in clusters. In future explorations, because we expect to observe more cases of boulder-rich surfaces, the characterization of the size-frequency distribution (SFD) will be important especially for the missions involving a lander such as MMX. Basically, measuring the SFD of boulders on a surface is expected to represent that of the interior. However, considering that surface boulders can hide the underlying boulder, it is not clear that the SFD in a volume can adequately be represented by its surface. Therefore, in this work, we focus on how accumulating boulders with a known SFD appear from above.

In order to compare the SFD on a surface with that of a volume, the initial SFD has to be known. For the initial study, numerical simulations are convenient, because they can easily prepare the suitable conditions. In the previous studies, spherical boulders were randomly distributed in three-dimensional space, and only those on the surface were automatically extracted and measured (Tancredi et al., 2015). It was found that the particle distribution on the surface well reproduces the overall particle distribution. We consider that there is room for improvement in the arrangement of particles and the measurement of particles. Thus, we implement a three-dimensional discrete element method using rigid spherical particles to simulate the accumulation of a boulder-rich regolith. We then measure particles one by one manually when viewed from above the surface. For initial conditions, we set the size and the number of boulders randomly as specified by the power law index of -3. During a simulation, particles are not initially adjacent to each other and are instead dropped from the height of 30 m above the 54 x 54 m planar surface. The total number of particles is changed from 3000 to 7000 in 1000 increments. After the simulation, the size and number of the particles are measured manually when viewing the surface from the vertical direction. Then we refer to Clauset et al. (2009) for fitting and evaluating the data using the p-value metric.

We find that the power law index of the SFD is low when the number of particles is 3000. This may be because the larger particles are not buried in the smaller particles, resulting in only the number of smaller particles being reduced when viewed from above. When the total number is 4000 or more in a volume and p-value is high, the surface power law index from the multiple simulations is consistent with the specified value of -3 for some cases.

The SFD observed on the surface corresponds to the SFD in the interior of the body for the following conditions: the thickness of the deposited particles is larger than the largest particle and the p-value is high. For more detailed analyses, investigating the effects of the number of simulations, the complicated shapes of boulders, and parameter studies are needed. In addition, for a deeper understanding of the problem, experiments in a similar condition to the airless bodies using simulated regolith particles such as UTPS-TB and UTPS-IB (Miyamoto et al., 2018) are also required.

Keywords: Discrete element method, Boulder size-frequency distribution, Interior of small bodies

