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Fractal and fractional calculus to model hydrological processes with application to particle-based 2D and 3D landslide simulation

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We integrate existing soil infiltration modeling with particle based methods in order to simulate two and three-dimensional setups of triggered landslides. Commonly, the infiltration models are based on continuum schemes (e.g. Eulerian approach) by means of which it is possible to define the field of the pore pressure within a soil. By contrast, the particle based methods follow a Lagrangian scheme that allows one to identify the particle trajectories and their dynamical properties. In this work, in order to simulate the triggering mechanism, we apply the classical, fractal and fractional Richards equations and the Mohr-Coulomb failure criterion, adapted to the molecular dynamics technique. In our scheme the (local) positive pore pressure is simply implemented as a perturbation of the rest state of each grain. Therefore, the pore pressure function can be interpreted as a time-space dependent scalar field acting on each particle. To initialize the system we generate, using a molecular dynamics based algorithm, a mechanically stable disk (2D) or sphere (3D) packing simulating the consolidated soil. In this way, we can built the micro and macro pore structure related to different infiltration time scales. The inter-particle interactions are modeled with a Lennard-Jones like potential. The particle positions are updated in time, after and during a rainfall, with standard molecular dynamics. We analyze the sensitivity of the model with respect to the variation of some parameters such as hydraulic conductivity, cohesion, slope and friction angle, soil depth and fractional order of the generalized infiltration model. In addition, we consider both regular and random particle configurations. The results of our simulations are found to be in agreement with real landslides. In particular, the mean velocity patterns of the simulated landslides appear extremely similar to the observed ones. Moreover, it is possible to apply the method of the inverse surface displacement velocity for predicting the failure time. Therefore, we can claim that this is a promising new method to simulate landslides triggered by rainfall.