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Simulating the biomechanical behaviors of trees in granular-flow-forest interactions: MPM-LSDEM

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ABSTRACT

Forests, covering 39% of low-elevation mountains globally, are often considered environmentally friendly barriers against granular geophysical flows [1]. However, simulating the complex interactions between flow and forest presents significant challenges, including simulation of flow-tree contact and simulation of the biomechanical behaviors of tree. This study addresses these challenges by presenting a novel numerical simulator called MPM-LSDEM, which combines the material point method (MPM) and level-set discrete element method (LSDEM). The simulator uses the GJK algorithm [2] for contact detection and a sampling point level-set strategy to create a realistic contact manifold. The rotation of tree stems after the uprooting of trees is simulated using quaternions. The simulator is validated through comparisons with experimental results and analytical solutions. The findings from numerical parametric studies highlight that the interactions between overlapping bow shocks at the tree scale significantly influence the mobility of dry granular flows. Moreover, tree uprooting dissipates flow kinetic energy and reduces flow momentum, but it also produces timber debris, which intensifying the destructive potential of flows. The results from this study provide new insight for assessing cultivated or natural forest in their ability to mitigate granular geophysical flows.

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