Resolved CFD-DEM Modeling of Debris Flows, Avalanches, and Floods with Arbitrary-shaped Boulders and Driftwood Impacting Structures and Forests

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Geophysical mass flows, such as debris flows, avalanches, and floods, are often observed by the presence of large boulders and driftwood, whose shapes significantly influence the behavior of flow transportation, jamming, impact, and deposition. However, quantitatively assessing how the shapes of these large-sized solids alter flow behavior remains an open question. This challenge arises from complexities involved in capturing the interactions between fluids, arbitrary-shaped boulders or wood, and structures. In this study, we employ a newly developed resolved computational fluid dynamics and discrete-element method (CFD-DEM) framework to simulate the interactions between arbitrary-shaped solids and viscous slurry or water. Specifically, the shapes of boulders, driftwood, and trees are obtained from reduced-scale samples using X-ray computed tomography (CT) techniques, and the CFD and DEM models employ the immersed boundary method (IBM) and signed distance field (SDF) method, respectively. As a result, the proposed CFD-DEM coupling framework offers a unified treatment of fluid-arbitrary-shaped solids-structure interactions in geophysical flows. Through flows carrying wood and boulders against a slit dam and forests, we test the modeling capability and explore the effects of different shapes on flow-structure interactions. The high-fidelity numerical predictions of flow-structure interactions demonstrate reasonable consistency with experimental and real-world observations. Therefore, this physics-based model holds significant potential for geophysical flow hazard assessment and broader applications in nature and engineering scenarios. Acknowledgements: This research was supported by the UGC-PolyU Start-up Fund (Grant No.: A0049544).

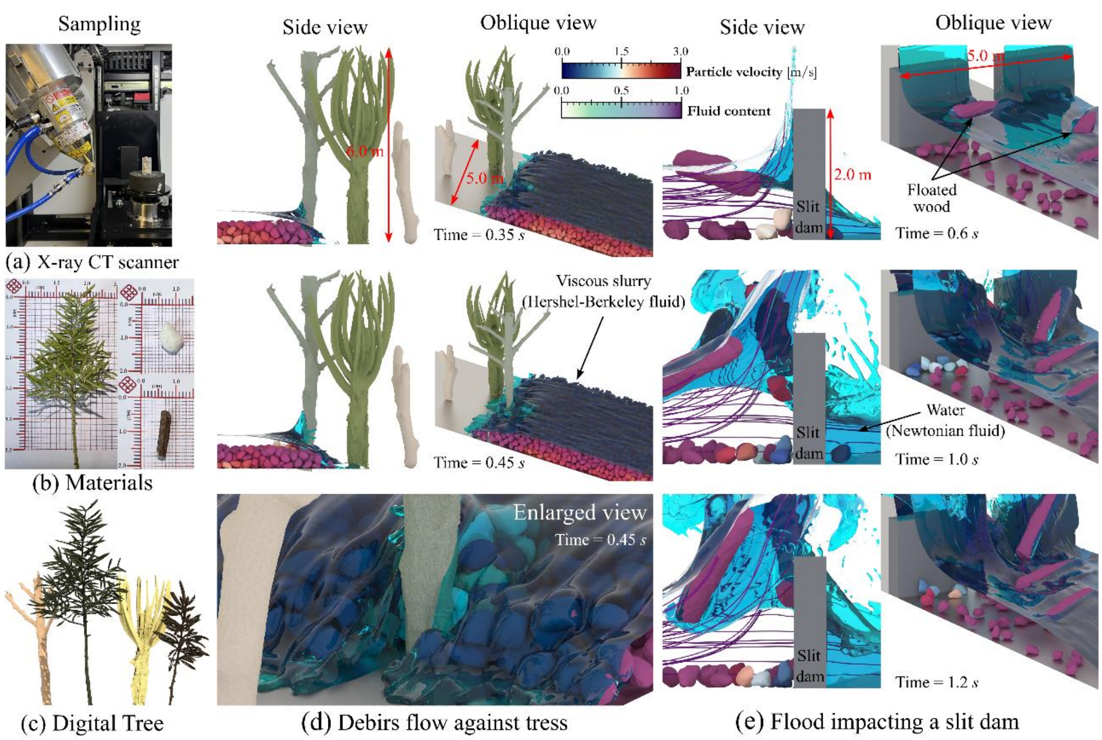

Fig. 1. CFD-DEM modeling of flows with boulders and driftwood against structures and forests