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TSUNAMI-DRIVEN DEBRIS EFFECTS ON STRUCTURES USING A MULTI-GPU MPM TOOL

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Abstract. Inundation events such as tsunamis and storm surges pose a significant threat to coastal communities and infrastructure around the world. The damage from such events is often not only the result of the flowing water itself, but also of transported debris. Such debris is composed of collections of whatever objects the inundation flows mobilize as they move through a stricken region, and can range from vehicles, to watercraft, to houses and small buildings. The purpose of our work is to address this challenge directly by experimentally and numerically studying flow-driven ensembles of debris impacting structures, with a focus on quantifying impact forces and damming effects in a manner valid for this kind of highly nonlinear, chaotic system. Among many possible numerical methods, the Material Point Method (MPM) emerges as most effective for modeling interacting deformable bodies. However, the method presents limitations on practical levels of resolution that can be achieved at scale due to computational costs. In this context GPU based MPM implementations offer an alternative approach. Graphics Processing Units (GPUs) accelerate Material Point Method (MPM) programs on the order of 100x, but limited memory and bandwidth restricts simulation size. Recent software advances in Computer Graphics now permit Multi-GPU MPM for engineering projects with many material points (10,000,000+) and grid-cells (1,000,000,000+). Hardware trends suggest rising GPU viability, with doubling of (i) video memory, (ii) bandwidth, (iii) computational cores, and (iv) increased accessibility in the next four years. We present our expansion of an optimized, open-source Multi-GPU MPM code (Claymore, https://github.com/penn-graphics-research/claymore) from computer graphics to engineering, where certain values (e.g., stress, strain, state-variables, forces) must be held to high standards. Building on open-source codes leverages prior development, requiring only basic I/O changes and vetting of physical accuracy (e.g., material models, shape-functions, transfer schemes). This code is used to model real-world flume experiments, performed in 12m x 0.9m x 1.2m (UW Flume) and 120m x 4.5m x 5.4m (OSU Flume) facilities. Stochastic debris-field transportation, jammed debris formations, and precise loadings are captured and extrapolated for probabilistic structural design against tsunamis.