Physics in the Rough: Geometric Algorithms for Coarsened Simulation

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Physical simulation is the job of constructing and implementing discrete structures to mimic behaviors in the world around us. From toy mass-spring systems to high-fidelity representations of reality, physical simulation plays a key role in how we exaggerate, interpret, mediate and predict events. Yet fundamental features of complex dynamic systems, including strong nonlinearities, frictional contact, impact and nonconvexity, pose significant challenges to computation at the high-speed rates required by modern research, entertainment, and industrial applications. To make these applications tractable we necessarily turn to highly coarse representations and often even low-precision solves. And while classical analysis can sometimes provide guarantees for our simulations at high resolutions with accurate solves, all bets are off when we violate these base assumptions. Nevertheless, physical systems must be modeled and, in turn, these models will necessarily be roughly discretized and simulated. It is thus critical to consider how the resulting behaviors of these rough simulations can best be understood, solved and validated. In turn this leads us to ask how can we compute predictive and compelling coarse simulations. Or put simply: what can we squeeze out of simulation "on the cheap"?

In this talk I will present some of our recent investigations towards answering these questions. First, I will discuss our work on designing a coarsening algorithm for the efficient yet predictive simulation of impacting elastica at practical-size time steps and spatial resolutions. Second, I will present a new optimization method for minimizing distortion under extreme deformations at efficient rates. Throughout I will focus on the role geometry plays in these domains and cover a range of applications that our methods enable ranging from the design optimization of 3D-printed jumping mechanisms, to the predictive simulation of emergent patterns in oscillated granular beds, and on to the live-broadcast animation of performed cartoons.

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