Position Based Snow Simulation with Phase Change
位置ベース法に基づく相転移を伴う雪のシミュレーション

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Snow is the most common winter scene in animation. The simulation of snow is widely used in various places. Most snow are naturally accompanying with abundant water resources. When the environmental temperature is near to the melting point, the existence of water will make the snow have drastic phase changes. This leads to different elastoplastic characteristics of snow and will further affect the formulation of snow shape. Therefore, it is necessary to simulate both solid and fluid water in order to increase the realism of snow simulation.

In our research, we introduce a method based on Position Based Dynamics by using two different discretization methods, Discrete Element Method (DEM) and Smoothed Particle Hydrodynamics (SPH) to simulate the interaction of surrounding water and ice crystals in snow. By introducing stretch constraints to DEM particles which performs as the interlinks of snow particles, we successfully simulate the deformation effect. In addition, we address the problem of over-connected interlinks by controlling the number of connections with considering the homogeneous freezing effects of ice crystals in snow. Also, to simulate the interaction of snow and its melts, our methods transfers the heat by using a conduction model for heterogeneous materials and the phase of a particle will be determined based on its current temperature. We blends the contribution of solid and fluid solver to imitate the latent heat effect and successfully stabilize the simulation.

In addition, we develop a fully GPU-based algorithm which addresses the complex implementation of phase-change problems. Since the transition of a particle from one phase to another creates empty spaces in memory which yields low performance on GPU computation, a parallelized exclusive scan is performed so that a compacted array can be obtained after the phase change. Furthermore, to prevent the read/write contradiction caused by the out-of-order execution on GPU, we utilize the atomic operations to comply the lock-free implementation of recording the information of interlinks.

As a result, our method is able to perform various characteristics of snow including deformation, phase change, and the rigid-fluid interactions. Despite of the limitations caused by our choice of constraint and the uniform size of particles, our position-based solver is a stable and controllable solution for simulating the complex behaviors of snow-water interactions.

In the future, we plan to simplify the need of parameter tuning by using XPBD to allow user to reference to real-world measurements. Also, we expect to extend our simulator to make it possible to interact with other objects so that it can be used to simulate various scenarios.

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