# Towards a Monolithic Discrete Element and Multi-physics Solver Utilising the GPU

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## Abstract

The rapid growth of general purpose GPU (GP-GPU) computing has seen meshless point-wise (or often referred to as particle based) partial differential equation solvers become attractive due to the highly parallelisable nature of these solvers [1]. Specifically, these solvers are able to exploit the single instruction, multiple thread (SIMT) paralllesism of the GP-GPU. Smoothed particle hydrodynamics (SPH) [2], proposed in 1977 by Gingold and Monaghan, is but one of many particle based solvers, and also the one we will be considering in this study. SPH is a mesh-free Lagrangian based method that looks at specific point-wise fluid "particles" in the spatial domain that contains fluid information at their current spatial points. An interpolant that represent the continuous fluid over the entire spatial domain is built by using a kernel function. While SPH has primarily been used for fluid simulations, it has also been shown as a promising method for simulating other physical phenomena such as heat transfer or elastic deformation of structures. With this in mind, a natural extension that comes from SPH's adeptness to solving a wide range of physics problems is to couple different problem types inside a multi-physics environment. Following on this idea, this paper looks at the specific coupling between solid-fluid at various length scales starting at fine scale particle models where interaction follow from a two-phase flow regime up to sufficiently large discrete element modelling (DEM) of particles where surface stresses are recovered from fluid equations and used to determine fluid force acting on DEM particles. On the one hand the two-phase flow regime is a purely SPH based model, while on the other hand the large discrete element modelling (DEM) requires coupling between the SPH and DEM models. For the latter this study focuses on the monolithic coupling between the DEM and SPH models which allows us to further explore the parallelism benefits of the GPU across solvers.

## References

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