Semi-decoupled kernel corrections for Smoothed Particle Hydrodynamics

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ABSTRACT

The SPH method, initially formulated to solve astrophysical problems, due to its meshfree condition, has proven to be a very efficient tool for modeling various phenomena such as free surface flows, incompressible fluids, water waves, interactions of fluid structure, etc. However, at least one problem with the standard SPH method is the inability to correctly describe the derivatives of a field due to particle inconsistency, which leads to low accuracy and, in some cases, to instabilities. Liu et al. [1] proposed a set of correction formulas, finite particle method (FPM), for both the functions and its derivatives, by imposing that the polynomials up to the first order and their derivatives are exact for any arbitrary configuration of interpolation points. This modification provides a method with higher precision than the traditional SPH, however, it requires inversion of a matrix (3×3) in two dimensions (2D) and one of (4×4) in three dimensions (3D). For the next order corrections (second order polynomials) the order of the matrices increases to (6×6) for 2D, and, (10×10) for 3D. This may lead to problems when the matrices to be inverted are ill conditioned. Recently Zhang & Liu [2] argued that in most of the cases the matrix can be approximated by a diagonal matrix, which simplifies the numerical implementation and in the same time acts as a natural mesh reordering preventing as well unphysical clustering and void formations. Our tests show that this decoupled FPM (DFPM) is not suitable for studying the flow of fluid around solid obstacles and propose an alternative semi-decoupled FPM (SDFPM) which has almost the same accuracy as the orginal FPM. In the SDFPM, we use the exact one dimension FPM formulas to estimate the derivatives for each component. These estimates use only (2×2) matrices for first-order corrections, for both 2D and 3D, whereas in the case of second-order corrections, (3×3). The proposed method provides significantly better estimates for the derivatives of the fields near the solid boundaries or in the cases of very disorder configurations at a minimum extra cost compared to the DFPM.

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