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Discrete Conservation in Meshfree Methods for Fluid Flows

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Over the last few decades, meshfree or meshless methods have become a popular alternative to conventional mesh-based solution procedures, especially for fluid flow problems with time-dependent domains and rapidly changing free surfaces. They can be easily used in a Lagrangian framework, which enables them to easily model large deformations and displacements. However, these advantages naturally come with their own challenges. One of the biggest drawbacks of meshfree methods is the lack of discrete conservation.

In this talk, we present an overview of different aspects of conservation issues in meshfree methods. First, we discuss the lack of formal conservative properties inherent in the derivative approximation procedure across most, if not all, “purely” meshfree methods. Central to this is the lack of a discrete Gauss theorem, and the absence of a natural way to define fluxes. We show that obtaining formal conservation in this setting necessitates a global computation of discrete differential operators, which makes the solution procedure very slow and not feasible for Lagrangian frameworks. To avoid this, we introduce a method of approximate flux conservation in meshfree methods.

While focusing on incompressible flow, we also present the issue of volume and mass conservation in Lagrangian meshfree frameworks. We then introduce a concept of representative masses in Lagrangian meshfree collocation methods that can reduce the impact of these issues. We further introduce a notion of mass transfer between collocation “particles” that ensures the notion of representative masses can also be used for complex flow problems with large deformations in the fluid domain. After a series of verification and validation test cases that highlight the impact of the introduced framework, we also present the application of the method to an industrial test case of automotive water crossing.