A unifying constraint–based formulation for freely moving immersed bodies in fluids

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Numerical simulation of moving immersed bodies in fluids is now practiced routinely following pioneering works of Peskin and co-workers on Immersed Boundary Method (IBM) and Glowinski and co-workers on Fictitious Domain Method (FDM). A variety of variants of these approaches have been published, most of which rely on using a background mesh for the fluid equations and tracking the body using Lagrangian points. In this talk, generalized constraint–based governing equations will be presented that provide a unified framework for various immersed body techniques. The key idea that is common to these methods is to assume that the entire fluid–body domain is a “fluid” and then to constrain the body domain to move in accordance with its governing equations. The immersed body can be rigid or deforming. The governing equations are developed so that they are independent of the nature of temporal or spatial discretization schemes. Specific choices of time stepping and spatial discretization then lead to techniques developed in prior literature ranging from freely moving rigid to elastic self-propelling bodies. To simulate Brownian systems, thermal fluctuations can be included in the fluid equations via additional random stress terms. Solving the fluctuating hydrodynamic equations coupled with the immersed body results in the Brownian motion of that body. The constraint–based formulation leads to fractional time stepping algorithms a la Chorin–type schemes that are suitable for fast computations of rigid or self-propelling bodies whose deformation kinematics are known. Application of this technique to problems such as aquatic locomotion, underwater vehicles, car aerodynamics, and esophageal transport will be summarized.