An Alternative to FEM and Meshfree Methods - The ALE IFEM

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The Immersed Finite Element Method (IFEM) combined with the Arbitrary Lagrangian Eulerian (ALE) approach is proposed to solve complex fluid-structure interaction problems such as deformable structures with various material laws interacting with suspending fluid in biological flows.

Most common approaches to simulate fluid-structure interaction including deformable structures treat fluid-solid interfaces explicitly and, therefore, need to update the fluid domain position within each time step to follow the solid surface. Severe solid deformation leads to fluid mesh distortion and requires re-meshing in ALE methods. In meshfree methods, updating the fluid domain results in heavy computations of the meshfree shape functions and their derivations.

The Immersed Boundary (IB) method provides the concepts of simulating elastic structures on a fluid grid without treating fluid-solid interfaces explicitly, which relieves the burden of mesh update. In the IB method, the solid and fluid domains exchange forces and velocities by a Dirac delta function. The recently proposed IFEM extends this concept by using the Reproducing Kernel Particle Method shape function as the discretized Dirac delta, which allows the usage of non-uniform grids for both fluid and solid domains.

To improve accuracy and efficiency by having a fine fluid grid only near the structure, we use the ALE concept to update the fluid mesh. The advantage of ALE IFEM is the additional freedom in describing the fluid grid movement compared to ALE. This ALE IFEM example also shows how meshfree methods can benefit from the IB concept.

References

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