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Conclusion

In this thesis we proposed a new formulation for the direct numerical simulation of one or more Newtonian incompressible and immiscible fluid phases with suspended and floating rigid particles that is based on the fictitious domain method using Lagrange multipliers. We recall that all previous works on this research area developed exclusively for particulate flow or floating particle simulations and our work allows for these physical phenomena in a single numerical framework.

Our finite element numerical solver uses an implicit approach for time discretization and Newton's method for efficiently solving the fully coupled non–linear system of equations obtained at each time step. This differs from previous works on this area that usually use confusing and extensive explicit projection methods to perform the numerical solution of particulate flow problems.

We also propose a new scalable topological data–structure for mixed triangle and quadrangle finite element meshes that is compact and uses integer containers and a set of arithmetic integer operations instead of the pointers used in classical data structures. Our fictitious domain implementation was also described and is based on inheritance features of objects included in a modern programming language like C++. To do so, we propose a suitable and efficient hierarchy of classes based on the work of (4).

Our method and implementation were validated using different test problems that simulate the sedimentation and the flotation of one or more cylindrical particles. The results obtained were compared with previous numerical and theoretical results and we showed that they have an excellent agreement with expected physical behavior. Moreover, we performed tests in more complex examples that have not been well studied in previous works.

We are planning to extend this work to perform 3–dimensional simulations and its adaptation for real life applications such as sedimentation problems and the manufacturing of ordered monolayer of micro and nano particles. The technique seems to be a very promising tool to study these physical phenomena using direct numerical simulation.