



INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI
SHORT ABSTRACT OF THESIS

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Thesis Title : A Generic and Robust Numerical Framework for Multiphase Flows using Volume-of-Fluid/Immersed Boundary Methods
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SHORT ABSTRACT

The thesis presents the development of a multi-fluid/multiphase flow solver for numerical simulations involving immiscible and miscible fluid flows with large density ratios interacting with multiple stationary and/or moving rigid solids. We discuss the development of a two-dimensional, incompressible, finite volume solver employing a novel hybrid staggered/non-staggered framework wherein a single normal momentum equation is solved at the cell faces. The framework then integrates several strategies, based on the volume-of-fluid method in a unified manner, to simulate multi-fluid/multiphase flows those are frequently encountered in practical and engineering applications. We first propose generic guidelines for the development of interface capturing schemes for accurate resolution of interfaces between immiscible fluids. These guidelines are used to devise two new interface capturing schemes and their capability is analysed in typical advection tests where they are found to be as good as and sometimes even superior to existing schemes on structured and unstructured meshes. Subsequently, these schemes are coupled with the normal momentum equation in the hybrid staggered/non-staggered framework for multi-fluid simulations and preliminary validation studies are carried out. However, fluid flows with large density ratios are prone to numerical instabilities which often arise in surface tension and gravity dominated flows. To address these issues, we have developed and implemented a well balanced and consistent formulation for multiphase flows. We enforce the consistency by transporting the volume fraction and momentum using identical high resolution schemes at the discrete level while the balancing is ensured by discretising the competing forces in the momentum equation at the same discrete locations using suitable gradient operators. Extensive studies to highlight the importance of force balancing and consistent convective fluxes are presented in the thesis. A novel diffuse interface immersed boundary method is then incorporated in the algorithm to handle the interaction between one or more rigid bodies and multiple fluids. This method exploits the numerical philosophy of the volume-of-fluid approach and is totally devoid of any interpolation strategies. Interestingly,

it solves for an unified momentum equation everywhere in the domain depending on the solid fractions of the rigid bodies. The immersed boundary-finite volume solver is shown to be nominally second order accurate with much lesser spurious force oscillations and its robustness and viability is demonstrated on a wide range of problems that include water entry of circular cylinders and two-particle sedimentation in homogeneous and stratified media. As a first step towards extending the scope of the proposed methodology, we also add capabilities to the solver to investigate interaction of miscible fluids and some applications in micromixers are studied. To conclude, we present an efficient and simple incompressible immersed boundary-finite volume multiphase flow solver devoid of reconstruction and sophisticated numerical strategies that may prove to be a robust alternative to the existing multiphase flow algorithms.

