Modeling of multi-phase flows with a Level-Set method

S.P. van der Pijl, G. Segal, C. Vuik, P. Wesseling
Applied Mathematics Department, TU Delft

Introduction

Aim of the project is to model multi-phase flows. Application to mixtures of oil-bubbles in water and water-droplets in air. Aspects which are taken into account are: a sharp front (density changes rapidly), arbitrary shaped interface, surface tension, buoyancy and coalescence of drops/bubbles. Attention is paid to mass-conservation and integrity of the interface.

Governing equations

Flow is goverened by the incompressible Navier-Stokes equations. Fluids are separated by immiscible interfaces. *Interface conditions* express continuity of mass and momentum over the interface.

Computational method

The computational method is a combination of the Level-Set and Volume-of-Fluid methods. The flow is computed by the pressure-correction method with a Marker-and-Cell layout. Interface conditions are satisfied by means of the *GhostFluid* method for incompressible flows.

Motivation

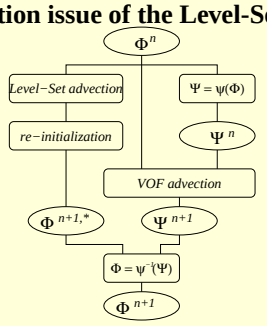
An implicit definition ('fixed grid') of the interface by a *marker function* is favorable in case of a complex shape. Such methods include Level-Set and Volume-of-Fluid.

Level-Set

The interface is defined by the sign of the marker function. **Advantages**: **elegant**, evolution of the interface by methods available from hyperbolic conservation-laws, smooth marker function near interface → easy to compute normals and curvature. **Disadvantage**: advection of the interface is **not mass-conserving**.

Volume-of-Fluid

Definition of interface: value of marker function indicates corresponding fluid. **Advantage**: advection of the interface is in principal **mass-conserving**. **Disadvantages**: elaborous, discontinuous marker function near interface → normals and curvature not easily computed.
The Volume-of-Fluid method is used to resolve the mass-conservation issue of the Level-Set method.



GhostFluid

Straightforward extentension of a single-phase flow solver to multi-phase without any smoothing of interface forces. Applicable in combination with the Level-Set method. Interface conditions are satisfied by a prescription of *jump conditions*.

Current status

The method is capable of computing a two-dimensional falling drop of water in a container. The density ratio water/air is one thousand. The grid consists of 80×80 points. Some snapshots are presented below.