# 2011 Special Program: Two-Phase Flow, Interface Flow and Related Phenomena

## *A joint method of level set and direct-forcing immersed boundary for fluid-structure interaction with free surface*

2011 - 12 - 28 (Wed.)
15:00 - 17:00
308, Mathematics Research Center Building (ori. New Math. Bldg.)

Fluid-structure interaction problems have been a challenging subject for computational fluid dynamics, not to mention if the problem involves a free surface between two fluids such as water and air. While level set methods have been celebrating huge success than ever in simulating two-phase flows, various novel and efficient immersed boundary methods have been recently applied successfully to solve difficult fluid-structure interaction problems. However, few methods were reported to solve the fluid-structure interaction problems involving free surface, which can be seen as a kind of three-phase flow problems. Those methods are difficult to implement, which motivated us to develop an efficient joint method of level set and immersed boundary for it. Here incompressible Navier-Stokes equations together with the level set equation are discretized by finite difference method in simple staggered Cartesian grids, with the accuracy of order in space is 2nd order, featuring central difference for the viscous term and 2nd-order upwind scheme for convection term. Projection method is employed here with pressure Poisson equation to replace divergence-free condition. 2nd-order Adams-Bashforth method is used for the time-integration of convective and viscous terms, and forward Euler method for pressure and force terms. A 5th-order WENO scheme is used to solve the level set equation to track the interface of two fluids with surface tension that requests very high accuracy. As to the solid part, an immersed boundary method with direct forcing is applied to simulate

a solid object moving in two fluids. Volume of solid interpolation is employed to obtain further accuracy in space for flow near the solid. The whole method is validated with a 2D uniform flow past a circular cylinder with vortex shedding. Coefficients of drag and lift, Strouhal number were computed and are all very accurate compared with literatures. Several cases of fluid-structure interaction computational examples are shown to demonstrate the excellence of the current method. In conclusion, our current method is efficient, straight-forward, robust and successful in solving fluid-structure interaction problems with free surface involved.