GPGPU based contact simulation between a rigid body and fluid by using incompressible SPH

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Abstract

Offshore construction for the marine resources development might encounter sloshing and slamming problems. These problems include the strong nonlinear free-surface flow and impact load of fluid. The moving particle method for the nonlinear free surface problems has been used. The existing SPH method which is a kind of the moving particle method has a problem when the flow field is unstable by non-physical pressure fluctuation over the time or space. Since the state of equation (EOS) calculates the pressure by assuming that the fluid has a little compressibility, the pressure fluctuation is occurred by a little error of particle density for each fluid.

The particle density of fluid is assumed to be constant and projection method is used to solve the velocity-pressure coupling problem. The pressure poisson equation is calculated by using the obtained correction density of fluid particle in the prediction step. The governing equations are the continuity and Navier-Stokes equation as shown in the equation (1) and (2).

$$\frac{1}{\rho}\frac{d\rho}{dt} + \nabla \cdot \vec{u} = 0 \tag{1}$$

$$\frac{d\vec{u}}{dt} = -\frac{1}{\rho}\nabla p + \nabla \cdot (\nu \nabla \vec{u}) + \vec{F} \tag{2}$$

ρ is density, $\vec{u}$ is velocity vector, t is time, p is pressure, ν is coefficient of viscosity, $\vec{F}$ is body force. Since the ISPH method handles with the non-incompressible fluid, the density is always constant. Then, the governing equation (1) is expressed as follows.

$$\nabla \cdot \vec{u} = 0 \tag{3}$$

The governing equation (2) can be expressed like the equation (4) by summing and subtracting the auxiliary velocity $\overrightarrow{u^*}$ on the left term.

$$\frac{\overrightarrow{u^{n+1}} - \overrightarrow{u^*} + \overrightarrow{u^*} - \overrightarrow{u^n}}{\Delta t} = -\frac{1}{\rho}\nabla p + \nabla \cdot (\nu \nabla \vec{u}) + \vec{F} \tag{4}$$

The kernel function plays an important role with regard to the solution in the incompressible SPH method. Figure 1 shows the relation between a particle and other particles within the support domain by the kernel function. Figure 2 shows the dynamic behavior of a rigid body in the fluid.

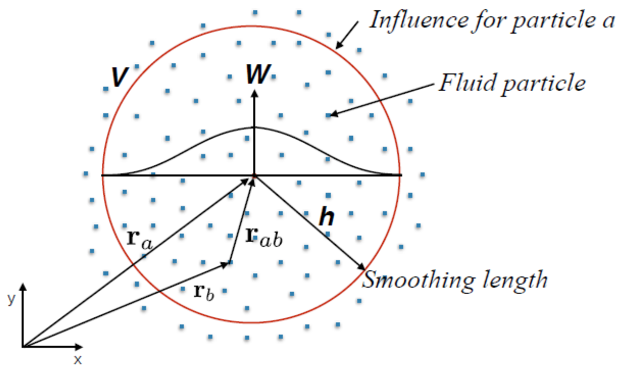

Figure 1: Support domain of kernel function

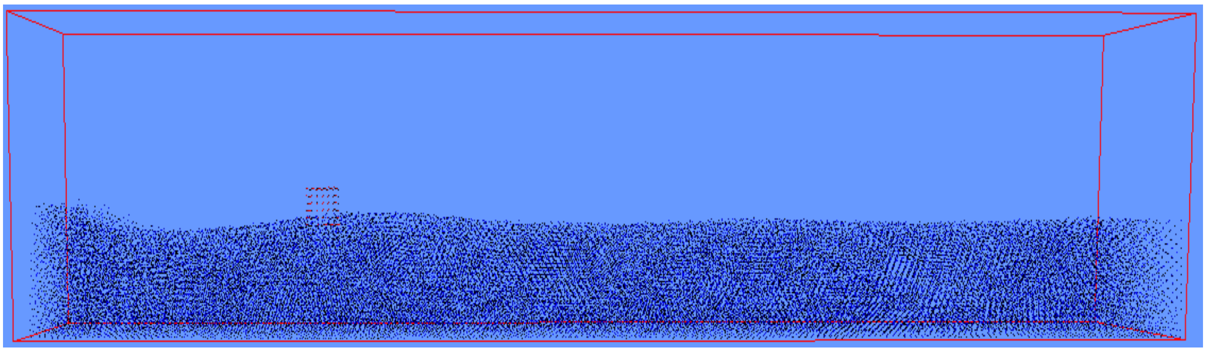

Figure 2. Dynamic behavior of a rigid body in the fluid

In this study, the dynamic behavior of a floating body in the fluid is considered. The SPH method and ISPH method are employed to analyze the interaction between the fluid and a rigid body. The results are compared with each other and differences of those are analyzed. GPGPU based parallel computing is used to improve the numerical efficiency in the computer simulation. The parallel program shows much more efficiency than the sequential program.

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