Level Set based Finite Element Method of Bubble-in-Liquid Simulation

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1 Introduction

There are various numerical methods to perform a direct numerical simulation of a bubble-in-liquid flow. Among them are level set method\(^[1]\), front tracking method, volume of fluid (VOF) and body fitted coordinate method\(^[2]\). Body fitted coordinate method is able to treat the jump condition across the phase interface most accurately since a body fitted structured or unstructured mesh around a bubble interface, across which singularity occurs, is generated. However, this method has a difficulty in solving the merging/breaking case of a bubble since the generation of a body fitted mesh of the case with time is formidable. Front tracking method adopts a structured background mesh in order to treat the singularity across an interface. However, it is quite complicated for this method to treat the merging/breaking case of a bubble. Compared with the body fitted and front tracking method, both VOF and level set method are easy to implement and the merging/breaking problem of a bubble is more easily treated. VOF and level set method use a background mesh, typically structured one, and the phase interface is defined by VOF and level set function, respectively. The physical understanding of both methods is straightforward since the evolution of an interface is obtained by the advection of the interface with time. However, VOF method has to perform an ad-hoc procedure\(^[3]\) to find the filling pattern of control volumes around interface, which is necessary step for the construction of a newly defined interface at each time step. On the other hand, the level set method does not require that procedure. Furthermore, the level set method has an advantage over other methods in that the interface with singularity is managed by the continuous level set function, which is differentiable, and the extension of a two-dimensional level set code to the three-dimensional one is straightforward. On the other hand, the level