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Using Graph Neural Network for gas-liquid interface reconstruction in Volume Of Fluid methods

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The volume of fluid (VoF) method is widely used in multi-phase flow simulations to track and locate a free surface. The relative volume fraction in each cell is used to recover the interface properties (i.e., normal, location and curvature). The accuracy of the computation of the local interface curvature is essential for the evaluation of the surface tension force at the interface. Unfortunately, the computation cost of standard VoF methods [2] is a bottleneck for realistic large scale simultations.

Several attempts to apply machine learning approaches to this problem have been published recently. Qi et al. developed a neural network for 2D geometry trained with a synthetic dataset [3]. Patel et al. extended this approach to 3D geometry using a two-layer feed-forward neural network [4]. These approaches outperformed in many cases the standard methods, even matching the accuracy of the best ones. However, all these machine learning enhanced VoF methods apply to computations on a structured grid.

In this work, we propose a machine learning enhanced VoF method based on Graph Neural Networks (GNNs) to accelerate the interface reconstruction on general unstructured meshes. We use a synthetic dataset built with paraboloid surfaces discretized on unstructured meshes. Our approach is benchmarked to conventional methods in terms of accuracy and computational cost using the OpenFOAM framework on a variety of academic test cases.

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