Proceedings of the 1st international Symposium on AI and Fluid Mechanics
Abstract No S12 A1

Integrating Super-Resolution and Segmentation for Enhanced Bubble Identification in Multi-Phase Flow

[2]J.L.P. Costa 2; [2]Z. Kokkinogenis; [1]J.B.L.M. Campos;[1]M.C. F Silva

[1]Transport Phenomena Research Center (CEFT), Department of Chemical Engineering, Faculty of Engineering, University of Porto, Porto, Portugal

[2]Artificial Intelligence and Computer Science Lab (LIACC), Porto, Portugal

Abstract

Accurate segmentation of experimental fluid dynamics is critical for understanding multi-phase flow characteristics, particularly in systems involving diverse bubble populations. This study explores a novel framework that combines super-resolution (SR) techniques with advanced segmentation algorithms to improve the identification and classification of bubbles in experimental images. By enhancing the resolution of low-quality experimental footage, our method enables precise segmentation of flow features that are otherwise challenging to resolve.

To address the challenges of annotating experimental data, the framework incorporates an active learning approach to iteratively refine the segmentation model. Human-in-the-loop strategies prioritize the most uncertain or misclassified regions for labeling, significantly reducing the annotation burden while improving model accuracy. The segmentation pipeline is specifically designed to distinguish between different bubble types based on their morphology and dynamic behavior, even in complex scenarios involving overlapping and deformable structures.

Experimental data collected for gas-liquid bubbly flow is used to train and evaluate the framework, ensuring applicability to real-world flow systems. This super-resolution, segmentation, and active learning integration provides a systematic approach for extracting high-fidelity insights into bubble dynamics and their interactions in multi-phase flows. Applications span bubble column reactors, and other systems where understanding bubble behavior is critical to optimizing process performance.

2000 characters including spaces (1601)

Keywords: Super-resolution; Bubble segmentation; Experimental fluid dynamics; Multi-phase flow analysis; Active learning