Project Proposal

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Introduction

Rayleigh-Taylor instability (RTI) forms at the surface of contact between two fluids, one of which is denser and accelerates toward the other. Formations in RTI are not symmetric between the denser and lighter fluids, and the features of both sides serve to characterize the RTI. However, these features quickly rise in complexity, and it is unrealistic to simulate them beyond a given time threshold. In our project we hope to provide insights regarding structure that apply to RTI generally, including in the later stages of RTI development, using TDA methods.

Project Objective

In this project, we plan to explore various topological filtrations of RTI data to expose meaningful properties of the RTI. RTI is at a stage of development in which there are few, if any, application inspired motivations in its research. Instead, researchers in fluid dynamics simply seek to understand it more extensively. We hope to describe the structure of the formations in RTI using TDA techniques.

Data

Our dataset has to be simulated using the physics of bubble formation as briefly described in the introduction. In particular, we will use a set of points in $\mathbb{R}^3$ that also have viscosities and velocities. In the paper, the authors had access to a supercomputer, a resource that we do not have, so we must generate a significantly smaller simulation. Instead of the 1152^3 or 3072^3 data points, we will use 256^3 points. The reason for simulation stems from the obvious difficulty in precisely measuring bubble formation and maturation.

Background

Technical Contributions

Expected Outcomes and Deliverables

Evaluation

We should be

Proposed Methods

Software

For dataset generation for each time-step, we will possibly use C/C++ to speed up the process. From there, we will use Java or Python to generate a filtration of the Morse-Smale complex at each time-step (as well as other filtrations we may wish to try). Subsequently we will use Ripser to generate a persistence diagram. To generate critical points we are, as of now, unsure what software we will use or if we will write our own.

Timelines

Since we are attempting to reproduce the results of the paper, as well as do our own parametric analysis and perhaps try other filtrations, we will closely follow their TDA pipeline. Our rough project timeline is as follows:

Week 1: Analyze the paper carefully and create software to generate a data-set for each time-step.

Week 2: Learn how to extract isosurfaces at each time-step.

Week 3: Extract and store a combinatorial Morse-Smale complex for each time-step.

Week 4: Learn how to extract relevant homological information from the filtration necessary for the final step.

Week 5: Construct merge-trees to display results.

Week 6: Play around with parameters, prepare for project presentation, and begin work on final report.

Project Summary