SIMPLE implementation and temperature distribution around a 2D geometry

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Abstract Personal project proposal for the course ME663 - Computational Fluid Dynamics. Implementing SIMPLE algorithm to solve the Navier-Stokes equations for a 2D problem and analyze the temperature field around a 2D geometry.

Keywords CFD, SIMPLE, Temperature field analysis, 2D problem

1 Introduction

This project has been chosen to further explore the content of the course ME663 - Computational Fluid Dynamics and to apply the knowledge acquired trying to finally answer a personal question of interest.

Given that for the first assignment we have successfully implemented a 2D solver for the Navier-Stokes equations using the SCGS algorithm, we would like to further explore the topic of CFD solver by implementing in the same codebase the SIMPLE algorithm and compare the results of the two.

Time and capabilities / resources permitting, the second part of the project will be to analyze the temperature field around a 2D geometry, using the SIMPLE algorithm just implemented.

This study, is related to the author's interest in the problem of: *Investigating the flow velocity and temperature distribution around a pillar on a windy day to optimize well-being by identifying the most suitable positions to avoid exposure to cold temperatures.*

Up to now, we think that the implementation of the SIMPLE algorithm would be enough to be considered a personal project itself. However, we believe that the addition of the temperature field analysis would make the project more interesting and challenging.

2 Methods

The project will be divided into two main parts: the implementation of the SIMPLE algorithm and the analysis of the temperature field around a 2D geometry.

2.1 SIMPLE algorithm

The SIMPLE algorithm will be implemented starting from the same codebase used for the first assignment, which already contains the SCGS algorithm. The codebase has been written in `C` and from the beginning has been designed to be modular and easily extendable with new algorithms and features.

The SIMPLE algorithm will be implemented following the guidelines provided in the course notes and at first will be able to just solve the Navier-Stokes equations for a 2D problem (u, v, and p).

The code will be tested using the same test cases used for the SCGS algorithm, and the results will be compared to the ones obtained with the SCGS algorithm.

2.2 Temperature field analysis

The temperature field analysis will be performed using the same codebase and the SIMPLE algorithm.

Starting from the previously implemented code, the temperature field will be added to the solver, and the code will be tested against some known test cases.

If not treated during the course, the heat equation will be implemented starting from online resources.

Finally, we will use our code to answer the question of interest to us: *Investigating the flow velocity and temperature distribution around a pillar on a windy day to optimize well-being by identifying the most suitable positions to avoid exposure to cold temperatures.*

The problem will make of multiple simplifications assumptions, so to be simple enough to be modeled within our 2D solver, but at the same time complex enough to analyze a real world problem.

As a real world scenario where our analysis could be useful, we can think of a person waiting for a bus or a train on a windy day at a station with only a pillar that can be used as a shelter. At the end of the project, we will be able to provide a map of the temperature distribution around the pillar, based on the wind speed and direction. Multiple simple geometry will be tested (e.g. a circular pillar, a square pillar, etc.) and the results will be compared.

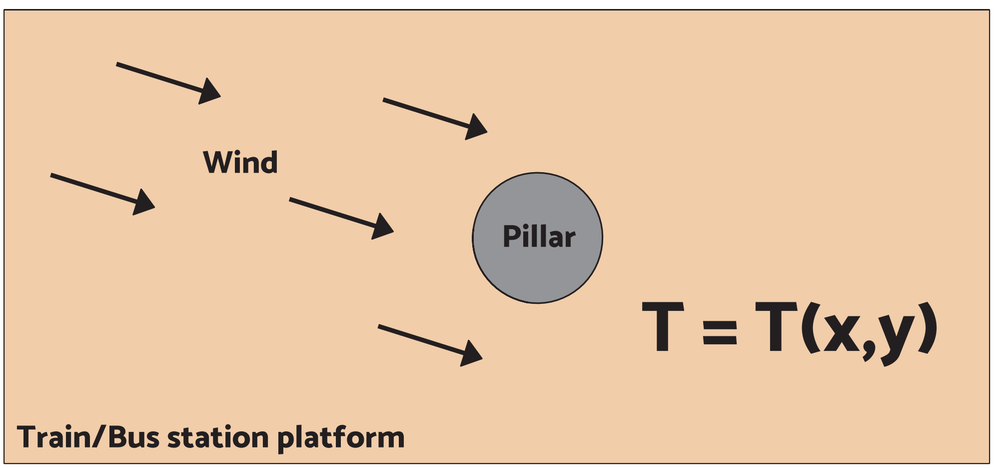

Figure 1: Problem drawing and real world scenario.

3 Expected Results

The main expected result of the project is the implementation of the SIMPLE algorithm. We will report the mathematical derivation of the algorithm, the implementation details, and the results obtained for the Lid Driven Cavity problem in the same PDF report used also for the first assignment.

The second expected (and optional) result is the analysis of the temperature field around a 2D geometry. We will report the mathematical derivation of the heat equation, the implementation details associated with the SIMPLE algorithm, and the possible results obtained for the problem of interest in a separate PDF report.

Up to now, we don't have the competences to use a commercial CFD software to compare our results with, and we highly appreciated if the professor could provide us with some results obtained with a commercial software to compare with (if possible).

In the end, we expect to have a better understanding of the CFD solvers at least for 2D steady-state problems, and to be able to have a higher self-consciousness about their implementation and their limitations.