Assignment on Lattice Boltzmann Methods

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Contents

1 General Remarks

- You can obtain a maximum of 1 EC in this worksheet.
- You can obtain a maximum grade of 8.0 or 10.0 if you chose to do the additional task.
- The report should be written in a way that your fellow students who are not attending the course should be able to understand it.
- To hand in your report, send it via email to:
  - Wouter (`w.k.denotter@utwente.nl`)
  - Kartik (`k.jain@utwente.nl`)
- Please attach the report to the email. For the report itself, please use the PDF format (we will *not* accept MS Word doc/docx files!). Include graphs and images into the report. You may write the changes in lua configuration files as verbatim codes. Reports prepared with *LaTeX* are greatly motivated and appreciated.

2 Theory of the LBM

Task (6 points)

- Explain the concept of collisions in the Boltzmann equation.
- How can the collisions be related to the viscosity of the fluid?
- Write down the lattice Boltzmann equation (LBE) and explain it.
- How do you derive velocity, density and pressure from the LBE?

Task (4 points)

- Explain the shortcomings of the LGA and the need for LBM.
- From your knowledge of fluid mechanics, comment 4 applications where you would prefer using LBM and also 4 other applications where you will not use it.

3 Simulations using the Lattice Boltzmann Method

Task (10 points)

- A folder that contains a test case has been provided as **stenosis_apie**. An additional document that explains installation of Linux subsystem on your windows computer as well as the *Musubi* LBM solver has been provided. The **stenosis_apie** folder contains:

  1. *vessel.stl*: A surface mesh that is a 3D model of the stenosis geometry.
  2. *mesh*: A folder containing the volume mesh to be computed by LBM.
  3. File *params.lua* that defines all the parameters for the simulation.
  4. File *seeder.lua* that defines the spatial objects for the creation of volume mesh.
  5. File *musubi.lua* which contains the physics information to run LBM simulation with *Musubi*.
  6. File *printsimparams.lua* which just prints out the parameters on the screen.

  You do not have to worry about the details in the lua files in the first step. Everything has been setup in a way that if you run it, your simulation will execute about 1 physical second of physics. In the end you will have some *vtu* files in the **harvest** folder[a].

  Depending on the CPUs on your computer, run *Musubi* with the command:

  ```
  $ mpirun -np 4 ~/musubi/build/musubi
  ```

  where 4 is the number of CPUs here, it might be 8 or more on your computer

  Now, please install the software Paraview[b]. In paraview you can visualize the **.pvtu** files.

- This task simply is to analyze the velocity, pressure and wall shear stress in the slice from the harvest folder and explain the physical details that you see therein. You should be able to look at the flow quantities and provide an explanation of physics thereof.

[a]Instructions for the installation of *Musubi* are provided in a separate document in detail. The document is called Mus_install_guide.pdf.

[b]https://www.paraview.org

4 Bonus task for better grade

Task (10 points)

In this task you can obtain 10 extra points and thus improve your grade.

- In params.lua the velocity of flow has been defined on line 18 as **umax**.
- Increase this velocity by 5% and run the simulation, analyze the physics as before.
- Decrease the original velocity by 5% and run the simulation, analyze the physics as before.
- Discuss in detail your findings. Compare and contrast the Physics of flow obtained from the simulations of Task 2 with the two simulations that you conduct in this task.
- Increase the original velocity by 8×. The simulation will most likely fail now with some NaN errors thrown out on the screen. Explain why did it fail!